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SEDIMENTATION AND STREAM IMPROVEMENT[1]

Robert P. Apmann Hydraulic Engineer
United States Department of Agriculture

Maurice B. Otis Supervisor of Stream Improvement
New York State Conservation Department

ABSTRACT

Changes in or adjustments of a stream channel, without protection of the stream geometry, can affect fish life. Stream channels are in delicate balance with their sediment loads and water discharges. Construction activities, including stream improvement, within a watershed, particularly those which encroach directly on a stream channel, must be based on a knowledge of stream behavior and sedimentation if unanticipated, detrimental changes in the shape and location of the channel are to be avoided. Valuable guidance regarding the effect of stream improvement designs may be derived from studying existing installations and correlating the circumstances involved with those in situations under consideration.

Fish life is affected by sedimentation, especially in streams. Apparently most fish can, themselves, easily withstand substantial amounts of sediment in suspension. Under prolonged exposure, about 20,000 ppm is required to cause death, and some species can tolerate 10 times that much (Wallens, 1951). But silt deposition greatly changes the environment for certain species by blanketing portions of the stream bottom, thereby eliminating potential spawning grounds and reducing the available food by killing many bottom-dwelling organisms. Silt screens out light and tends to hold extraneous substances, such as industrial wastes, on the stream bed. It also interferes with heat transmission and the physical properties of the water. Sand or silt shifting around on the bottom may eliminate shelter and food sources. In the long run, the slow accumulation of fine sediment is especially harmful. Cordone and Kelly (1961) pointed out, "Our failure to recognize that even small amounts of sediment may be harmful may well result in gradual destruction of the majority of our streams, while we work feverishly to solve more obvious and spectacular problems". Most of this fine sediment comes from erosion on agricultural lands, but some comes from eroding stream channels and from construction work on watersheds.

[1] Based on work carried on cooperatively by the New York State Department of Conservation, the U.S. Soil Conservation Service and the Cornell University Agricultural Experiment Station.

The outright destruction of fish habitat by various human activities is even more detrimental. In many instances, highways, bridges, buildings and other construction activities which encroach on stream channels require changing the channel shape and location and thereby destroy equatic life and habitat. The potential extent of such damage should not be underestimated because land use patterns are changing rapidly. The following graphic example, based on data from Montana, was given by Wolman (1964), "Highway and railroad construction have virtually eliminated trout from many miles of stream channel due to sedimentation associated with channel straightening, land clearing, and construction. It is estimated that approximately 78 miles of stream have been 'lost' in portions of Central Montana through such causes . . . On a tributary of Clark Fork of the Columbia River, successive studies of the trout population in a reach of river altered by highway construction indicated a 94 percent reduction in both numbers and weight of large size game fish in a period of two years."

Stream improvement can halt or minimize such destruction of fish life by providing the proper environment for survival, reproduction and growth. However, caution must be exercised because stream channels are usually in delicate adjustment with their water discharges and sediment loads. Without careful planning, both construction activities and conservation measures can upset these adjustments and lead to drastic and unplanned changes in shape and location. If proper aquatic environment is to be provided and maintained, stream improvements must be founded on the basic principles of sedimentation and stream behavior.

NATURAL STREAM ADJUSTMENTS

Stream channels behave in complex ways. Man has struggled with them for a long time, but despite a history of practical achievements, the scientific principles of stream behavior are just beginning to be understood.

Rivers and streams carry a mixture of sediment and water in normally well defined channels. The channel shape and location, or geometry, depend principally on the nature of the watershed. Precipitation on the watershed furnishes runoff water which erodes sediment and carries it downstream. If the stream bed and banks are erodible, they furnish additional sediment. A certain transporting capacity is needed to move the total imposed load. When the flow becomes overburdened with sediment some is deposited. However, if the load is less than the flow is able to carry, it seeks additional material from the channel to satisfy the demand. The transporting capacity depends primarily on the water discharge, the depth of flow, and the slope of the stream. These and other geometric elements of a stream are shown in Figure 1.

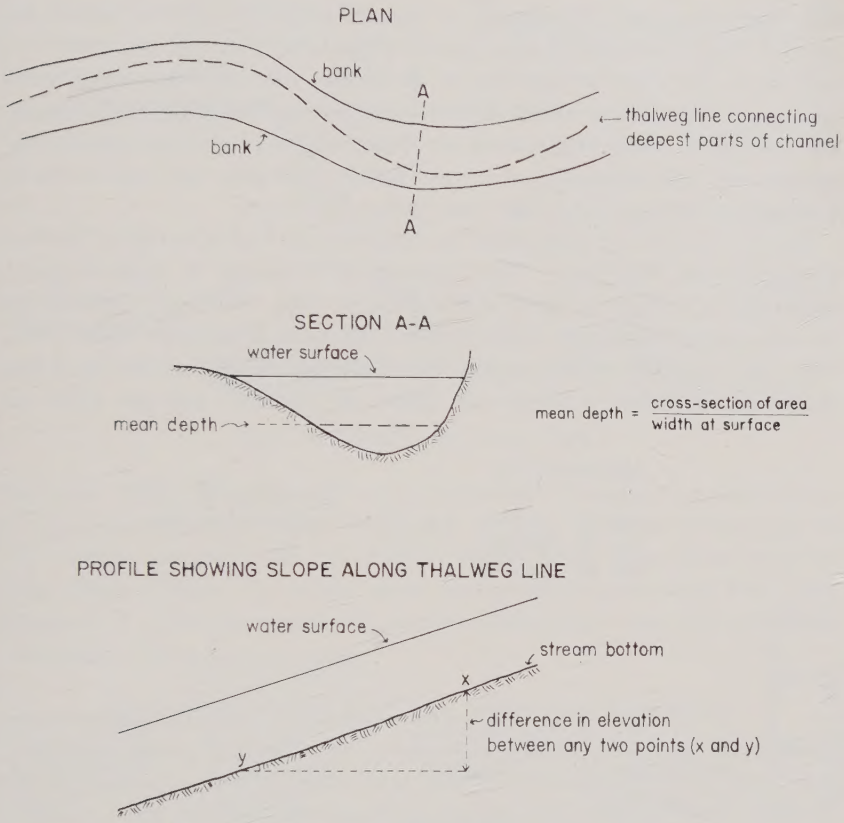

Figure 1. Some geometric elements of a stream.

Usually the geometry is delicately balanced with load and discharge. If they change, the stream adjusts its geometry to the new conditions. Steep streams seem to change their slopes in adjusting, but flatter streams tend to change their roughness by forming ripples or dunes.

These adjustments happen over different periods and at different points in the stream. Over an extended time, most streams slowly change their geometry in response to long-term changes in the watershed. For instance, the change might be a general uplift of the entire region. Some streams go through protracted cycles in which they may lower their beds, or degrade, and then raise their beds, or aggrade. However, most streams ultimately tend to degrade. The nature of these long-term movements is important in designing stream improvements, because the effectiveness of the work depends on the trend involved. For example, if a stream is degrading significantly, a bank revetment should be founded deeply in the stream bed so that erosion will not undermine the work. On the other hand, an extended aggradation trend would imply that bottom deposi-

tion was occurring. Treatment to control sediment sources would be needed. This treatment in turn would trigger other changes in geometry, and these, too, must be anticipated. In shorter time periods, adjustments will arise from normal storm activity and seasonal weather conditions in the watershed. Such adjustments are minor, unless caused by catastrophic events such as earthquakes or severe floods. However, the sum of these continuing changes yields the total stream geometry.

Surveys of the San Juan River in Utah by the U.S. Geological Survey (Leopold and Maddock, 1953) showed its response in cross-sectional geometry to changes in load and discharge. The river bed consisted of fine materials which were easily erodible. Between September 9 and 15 in 1941, the sediment supply to the river increased more rapidly than the discharge as shown in Figure 2. Since the capacity was too small to

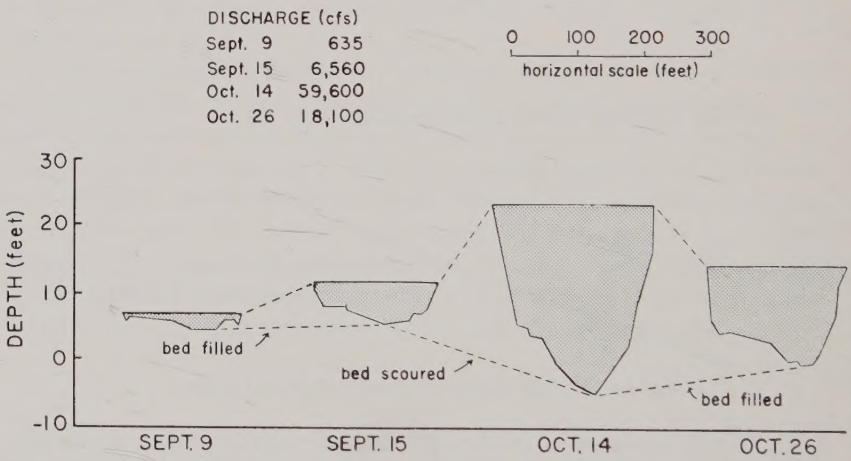

Figure 2. Adjustments of stream geometry to changes in load and discharge as illustrated by data for the San Juan River in Utah.

carry the load, some sediment was deposited and built up the bed. From September 15 to October 14, the discharge increased more rapidly than load. More sediment was needed to satisfy the capacity. This came from the bed, which was scoured and degraded. From then until the conclusion of measurements on October 26, the discharge dropped more rapidly than the load and the bed was filled again to attain the final adjustment. The cross-sectional pattern would not have varied so greatly if the channel material had been less erodible, as in the case of northeastern streams whose channels are formed close to bedrock and contain coarser material.

In addition to adjustments of this kind, more local changes within the channel also occur. They are created by obstructions or changes in

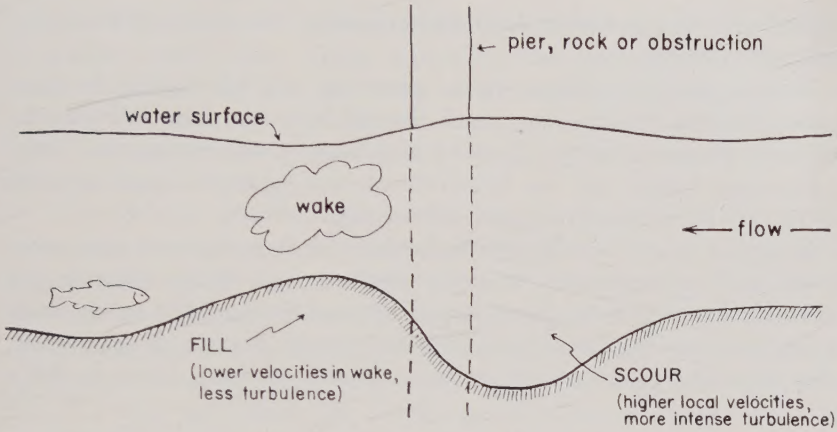

Figure 3. Obstructions create pools.

direction which bring about locally high velocities, intense turbulence, or secondary currents. River bends, for instance, tend to be scoured on the outside and filled on the inside. Bridge piers cause local scouring and filling (Figure 3). Large rocks also produce pools and bars. The amount of scouring caused by certain obstructions can be calculated (Laursen, 1962).

DIRECTLY CHANGING THE STREAM GEOMETRY

Certain stream improvement measures are specifically designed to bring about improved stream conditions. Boulder retards, rock and log dams, deflectors and cribbing all form local changes in geometry that are good for fish life. Retards and dams dig pools. Deflectors make a narrower, swifter and deeper channel. Cribbing protects banks and provides cover for fish (Otis, 1958).

It is important to realize that any changes made in the stream or in the watershed tend to cause new adjustments. For example, a significant amount of armoring revetment placed on the banks of a stream would reduce the sediment supply, thereby increasing bed erosion and degradation and requiring the revetment toe to be placed deep in the existing channel bed. Placing revetment in channel bends produces the greatest erosion reaction. However, boulder pool devices or timber structures placed in a stream without anticipating channel adjustments might cause a sizeable island to be deposited downstream, thereby creating an entirely new stream geometry.

Stream control measures can trigger such adjustments. Therefore, those concerned with stream improvement must anticipate the changes in stream geometry that might result from proposed improvements. Since local improvements may affect the whole stream, they should consider

full control of a watershed and improvement of the entire stream rather than spot control.

Human activities change stream geometry and fish habitat in many ways. Housing developments leave the soil bare for years and increase the load of fine sediment. Channel straightening and realignment without proper design and the indiscriminate use of heavy machinery are other examples of common and detrimental activities.

Economic needs to satisfy the demands of modern transportation sometimes justify realignments. However, highway and bridge designers are too often ignorant of the principles of stream behavior. They try to create a new geometry that is unlike the natural pattern. Because of topography, they sometimes encroach on stream channels or move them to other

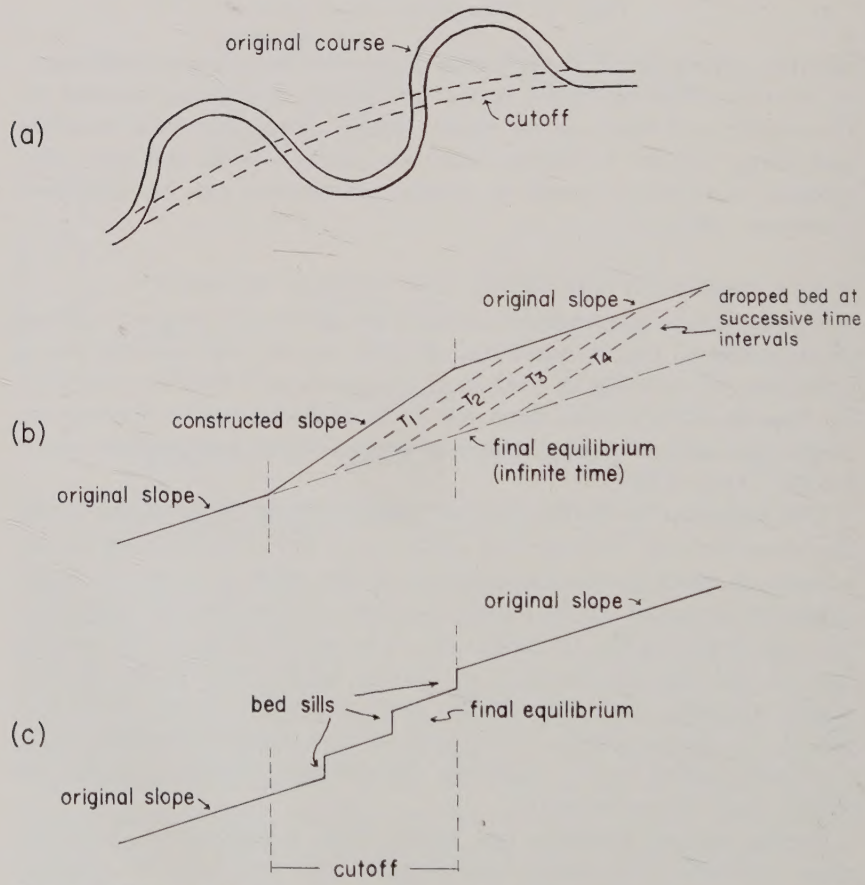

Figure 4. Diagramatic adjustments of stream to constructed increase in slope: (a) plan for short cutoff; (b) resultant profile with no bed protection; (c) resultant profile with bed protection.

places. This can create sedimentation problems, for cutoffs cause higher velocities which scour bridge abutments and embankments. Although many highway engineers understand these problems and endeavor to do a good job, they need additional information and knowledge of recommended procedures so that needed channel alterations can be made without serious consequences.

The problem may be illustrated by diagraming the results of constructing a cutoff to protect a meandering stream (Figure 4). A short cutoff with a gentle bend would be cheaper to stabilize than the long and sharply meandering stream. However, the cutoff would have a steep slope and, therefore, a greater ability for bed erosion. If the bed were not protected, it would progressively erode by headcutting (at times T_1, T_2, T_3, T_4, etc.) until finally the whole bed had dropped (Figure 4b). The end result would be gullying throughout the entire course and an increased rate of bank erosion. Bed protection by several transverse sills, as shown in Figure 4c, would help prevent this situation.

Damage of this sort can also result from other conservation practices. For instance, drainage is a major problem in farming. Better drainage can be achieved by clearing, snagging and straightening channels. But the greater slope and smoothness make the water flow away faster and increase erosion.

The marshes of the Pequest River in New Jersey afford an illustration, as reported by Apmann (1964). About 1,000 acres of valuable soil were being flooded each year and more than half the crops were destroyed every 5 to 7 years. The river was widened, deepened and straightened in 1954, while soil conservation practices were applied to the watershed. At the upstream end of the project, the old and new channels were joined by a short transition having a slope 14 times greater than the original as shown in Figure 5. No bed sill was constructed in this steep transition, thereby encouraging rapid headcutting which lowered the river bed upstream and endangered a nearby railway bridge.

Figure 5 also shows the adjustment in slope of the Pequest River over a 10-year period. Three test reaches were chosen on which bed elevations were surveyed 5 years after construction (i.e., in 1959) and also in 1964. The farthest upstream reach began just below the constructed steep transition. As headcutting occurred above the transition, the sediment was first carried into this reach, and its bed was built up about 2 feet higher than the constructed level. By 1964, the sediment wave had moved to the middle reach, and the bed there had been aggraded slightly. The railway bridge had been underpinned which then decreased the rate of headcutting farther upstream. The supply of sediment to the upstream reach diminished and its bed dropped almost to its constructed level. The lower test reach was also degraded. Possibly

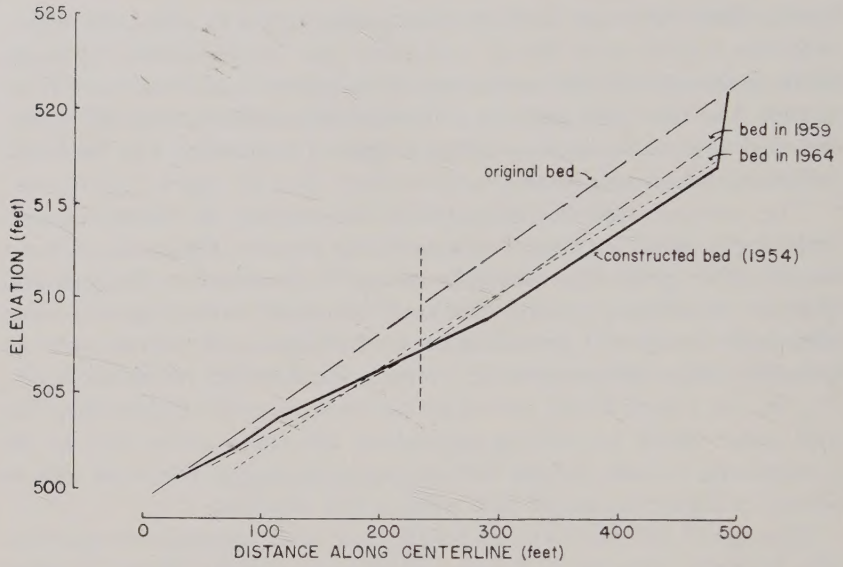

Figure 5. Adjustments of Pequest River in New Jersey following deepening of bed for drainage (after Apmann, 1964). Vertical dotted line represents point above which slope of bed tended to decrease and below which it tended to increase. In upper part bed first rose and then dropped; in lower part it dropped throughout period.

channel clearing farther downstream destroyed the original controls. Further measurements will be required to determine whether this degraduation trend will move upstream.

Because the constructed channel is not as rough as the original one, a lesser slope is required for adjustment of load and discharge. If soil conservation practices on the watershed are effective, they will have a similar influence. On the other hand, channel roughness is now increasing since vegetation is returning on the banks of the constructed section.

PROTECTING THE STREAM GEOMETRY

One objective of stream improvement work is to furnish the proper environment for fish by controlling sediment movement and stabilizing the stream channel. The specific jobs are to add fish cover, deepen or create pools, hold the stream bed stable, and retard the inflow of sediments from the watershed. The work has two aspects. If the existing geometry is desirable, it must be protected; if it is undesirable, it must be corrected and then maintained. In either case, the inflow of fine sediment and runoff water must be controlled, especially as land uses change. Stabilizing and protecting a disirable geometry is probably the most important.

The geometry may be protected in different ways (Miller and Parsons

1962). Generally, the best stabilization plan is one that is comprehensive (Francis and Andrews, 1962) involving bank protection, bed protection, reservoirs, and watershed treatment.

Bank protection can greatly reduce stream erosion and high sediment loads. Banks are frequently vegetated where stream forces are low. Both rigid and nonrigid materials can be used as linings or to divert the flow from the banks. Log cribbing can be built above the stream bed to obtain such benefits as bank protection, deep pools and ample cover for fish. Stone or concrete revetments installed in stream bends also form deep pools at the toe of the structure. Other devices, such as jacks, groins, diversions, and fencing to prevent overgrazing, are adapted to special conditions and are most effective when used in places which demand specific measures to protect the stream geometry.

If bank stabilization is to be successful, certain functional qualities in the structures used must be considered:

1. Durability against exposure to the elements and to the abrasive action of transported debris.
2. Stability against the fluid forces of the stream, the impact of transported debris, and the lifting action of ice.
3. Stability of the bank against slipping.
4. Complete effectiveness in preventing loss of subgrade or bank material by action of water at the boundary.

Bed protection is essential in stream cutoffs or realignments. Bed sills, constructed of resistant materials, are a simple and effective device as shown in Figure 4c. They maintain the desired grade of the stream bed and prevent headcutting upstream. Because the stream is prevented from cutting down its bed, it seeks sediment from bank erosion. Therefore, bank protection is also necessary in cutoffs.

Dams and sediment basins can be used to reduce flood peaks and downstream sediment flow. During the time needed to revegetate and reforest a watershed, temporary debris basins can aid in preventing siltation. They can also store the increased runoff caused by large urban developments.

Watershed protection measures conserve land and reduce sediment loads (Gottschalk, 1962). Furthermore, they increase water storage and can bring about year-around flows in some intermittent streams. Revegetation and the maintenance of large trees along streams increase insect life and provide shade which reduces water temperatures to benefit fish life.

CONCLUSIONS

Apparently, stream improvements are frequently installed without regard to the general status of the stream channel and its equilibrium.

Sometimes this is harmful. However, little is known about their exact effects in different streams. Conservation engineers should take time to study the installations under their control in order to learn their effect on stream geometry. Conditions will be found in which certain improvements caused rapid shifting of the stream channel and thus were unsuccessful, while in other circumstances they did the intended job. Such observations can be correlated with the type and characteristics of a watershed under consideration including such variables as watershed cover, soil type, nature of the stream channel, watershed area, and watershed slope. Generalized criteria will result from correlating successful work with particular conditions. Decreased installation and maintenance costs and increased effectiveness, not only in maintaining stream geometry but also in protecting and conserving fish life, should result.

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TOXICITY OF SEVIN (CARBARYL) TO FINGERLING BROWN TROUT

G. E. Burdick — Supervising Aquatic Biologist, New York State Conservation Department

H. J. Dean — Senior Aquatic Biologist, New York State Conservation Department

E. J. Harris — Senior Analytical Chemist, New York State Conservation Department

Jack Skea — Conservation Biologist, New York State Conservation Department

David Colby — Conservation Biologist (Trainee)[1], New York State Conservation Department

ABSTRACT

A comparative study was made of the toxicity of three preparations of Sevin to fingerling brown trout. Toxicity appeared to be bimodal. No significant difference was found between static and flow-through solutions. Sevin was found to be more toxic in aquaeous than in oil suspension after addition to water. It was also found to be less toxic in soft, acid water than in a harder, alkaline water. The effect of temperature was determined for a single concentration and is presented graphically.

A procedure was established for comparing toxicity within modes, based on the theory that comparison of the means of the mode in which 50 per cent mortality occurred in similar concentrations could be used to establish significant or non-significant variation between preparations.

It was found that size had a positive relationship to time for death. Accordingly, adjustment to a uniform fish size, based on a determined average correction factor, was used to reduce variability in data caused by difference in size. Graphical estimation of the logarithmic probability$_{50}$ was used to establish the point of 50 per cent mortality at each concentration. The antilog of the logarithmic probability$_{50}$ was plotted on logarithmic paper to form the toxicity curve. The toxicity of 50W Sevin was found to be slightly lower than the value derived by combining the data for 85P and 99T Sevin.

Sevin[2] (carbaryl), or l-naphthyl-N-methyl carbamate, is now used in this State for forest insect control where the use of DDT could result in contamination of pastures or forage and lead to residues appearing in milk. It is also used where application might result in the chemical being carried into lake trout waters. A difficulty in such use is its high toxicity to bees. A previous study, Burdick *et al.* (1960) indicated no apparent toxicity of Sevin to trout stream fishes when applied at a rate of 1¼ pounds per acre as an 85% micronized powder suspended in fuel oil and with the addition of a paraffin oil sticker.

Haynes *et al.* (1958) reported that 28 ppm of technical Sevin would produce a 50 per cent mortality in goldfish in 48 hours. The 50% wettable powder was stated to produce similar mortality at 14 ppm. No

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[1] Present affiliation: University of Massachusetts, Amherst, Mass.

[2] The authors wish to acknowledge the courtesy of the Agricultural Chemicals Division of the Union Carbide Chemical Company in providing samples of 99T Sevin and the 50W powder used in this study. Sevin is the Union Carbide trademark for carbaryl.

mortality was reported for 7.5 ppm of the wettable powder. One milliliter of ethanol was used to dissolve the technical material, and the difference in toxicity was suggested to be due to the greater solubility of the wettable powder.

In the present study acetone was used as a solvent in place of alcohol, and it was found that an increase in the amount of solvent prevented the rapid surface precipitation of the technical material which occurred when a high concentration in acetone was added to water. Under these conditions the two preparations did not differ as widely in their toxicity.

Henderson *et al.* (1960), using 95% technical Sevin dissolved in acetone before dilution in water, reported a 96-hour TL_m to fathead minnows of 6.7 to 7.0 ppm in hard water and 12 to 13 ppm in soft water. For bluegills the figure was 5.3 to 5.6 ppm in soft water. They also reported a 96-hour TL_m of 5.5 ppm for bluegills in soft water using the 50% wettable powder.

Cope (1963, Table 1B) reported a 24-hour TL_m for rainbow trout of 3.5 ppm and a 48-hour TL_m of 2.0 ppm, based on work by Bridges and Andrews.

PRELIMINARY EVALUATION OF AQUAEOUS SOLUTION

In 1960 a weighed quantity of 85% micronized Sevin was enclosed in a cylinder with a fritted glass bottom, and 1 liter of springwater was drawn slowly through it with an aspirator. The powder was then dried

Table 1. Preliminary Evaluation of the Toxicity of Sevin to Fingerling Brown Trout

Concentration	Tests	Number of fish in each	Volume of solution (milliliters)	Time for death (minutes)	
127.7	2	1	400	5, 5	*
63.8	1	1	400	7	*
31.9	1	1	800	8	*
16.0	1	1	1,600	15	§
8.0	1	2	1,600	19, 20	§
4.0	1	4	3,200	33, 82, >720	†

* Muscles of gillcovers became paralyzed making determination of time for death difficult.

§ Some motion after turnover.

† One fish recovered its equilibrium, but after 24 hours it was not normal, being sluggish and exhibiting persistent muscular contortions when touched with a glass rod.

and reweighed, and 127.7 milligrams were found to have passed into solution. While this may not be exact, as any soluble inert ingredients could have been included in the lost weight, most inert ingredients would not be expected to have significant solubility. It thus provides an upper limit for solubility. Back and Bagley (1959) reported 95% technical Sevin soluble only to 99 ppm, and a more recent publication (Union Carbide Corporation, 1965) listed the solubility as 40 ppm at 30° C.

This liquid was used to obtain a rough approximation of toxicity using progressive dilution at 60° F. Fingerling brown trout ranging from 47 to 68 millimeters in length were used in part due to the limited volumes available for testing and the reported generally higher susceptibility of fingerlings. As the undiluted extract had only 7.4 ppm of oxygen, the solution was aerated for 1 hour before the initial dilution. The data are presented in Table 1.

GENERAL PROCEDURE

Rome Hatchery springwater was used predominantly as the diluent of the chemical in determining the toxicity. An analysis of this water has been previously presented (Burdick *et al.*, 1954). Constant-temperature tanks were used, unless otherwise noted, to maintain a temperature of 60° F.±½°. Where flow-through was used in comparison with static solutions, the methods described by Burdick *et al.* (1958) were used, except that air pressure from a high pressure airline regulated by an oxygen pressure reducing valve was used to move the solution from the storage tanks to the experimental container.

Because these studies were conducted over a period of several years, some slight variability involved in combining data from several lots of fish could not be avoided. Staggering the progression of the concentrations was used as far as convenient to avoid the progressive increase or decrease in average size of the fish during the elapsed time involved in testing each lot over a number of concentrations. When the studies of a preparation were conducted over more than a single year, the data for the years were combined to provide an average for the different lots used. This procedure prevents ascribing to much significance to variations which were known to have occurred in individual lots.

Fish were measured to the nearest millimeter after death. They were acclimatized to temperature for 4 or more days (53° or 54° to 60° F.) and were unfed for approximately the same period of time.

Time of introduction, time of turnover and time of death were noted for all fish where possible. Time of turnover could not be noted in all instances. Fish were continuously observed as time of death was approached, and the time of death was recorded exactly except for a few instances where failure to note the exact time of death would not intro-

duce appreciable error (for example, near the end of an experiment of several days duration.)

Control experiments were used to assure that the stock fish would withstand the experimental conditions for a more extended period than those exposed to the toxicant under similar conditions. Any mortality shown by the controls was assumed to invalidate the use of the acclimatized stock for experimental purposes. Further mention of controls will not be made.

In static solutions a maximum of 10 fish for 16 liters of solution was used, and in experiments of several days duration this was reduced to 3 to 4 fish. Aeration was not found to significantly alter toxicity, and continuous aeration was used to prevent reduction of the oxygen concentration increasing the apparent toxicity in long-term experiments.

The testing procedure was designed to test the effect of a single application of Sevin, so, where flow-through was used, all the solution was made up at the same time. In static solutions there was no change of solution or replenishment to allow any changes resulting from time to take place. The effect of reduction in toxicity by removal of the toxic ingredient by the fish, or of increased toxicity from metabolic products, would be shown by plotting the data on logarithmic probability paper.

BIMODAL TOXICITY

The toxicity of Sevin to fingerling brown trout failed to follow a uniform logarithmic distribution for time for death at any concentration. A plotted frequency distribution seemed to indicate a bimodal distribution, although the numbers of fish were too small to provide adequate evaluation.

A normal distribution should plot as a straight line on logarithmic probability paper if individual mortality is plotted on the percentage scale against time. Individual times were thus plotted on probability paper (Codex Book Co., Norwood, Mass.). The presence of two slopes of mortality was confirmed. Each slope appeared to be log distributed. It was recognized that a skewed distribution could have a similar appearance. Skewness generally results from a different resistance in part of the population. Different concentrations were found to produce a shift in location of the two slopes. This would not conform to the theory of differential resistance within the population.

As an illustration slopes for two concentrations are presented in Figure 1. The initial phase is considered to be mode 1, and the less toxic phase to be mode 2.

Sevin is reported to hydrolyze to l-naphthol in alkaline media, rapidly at a high pH and temperature (Back and Bagley, 1959). The distribution in Figure 1 could have been caused by hydrolysis of Sevin over

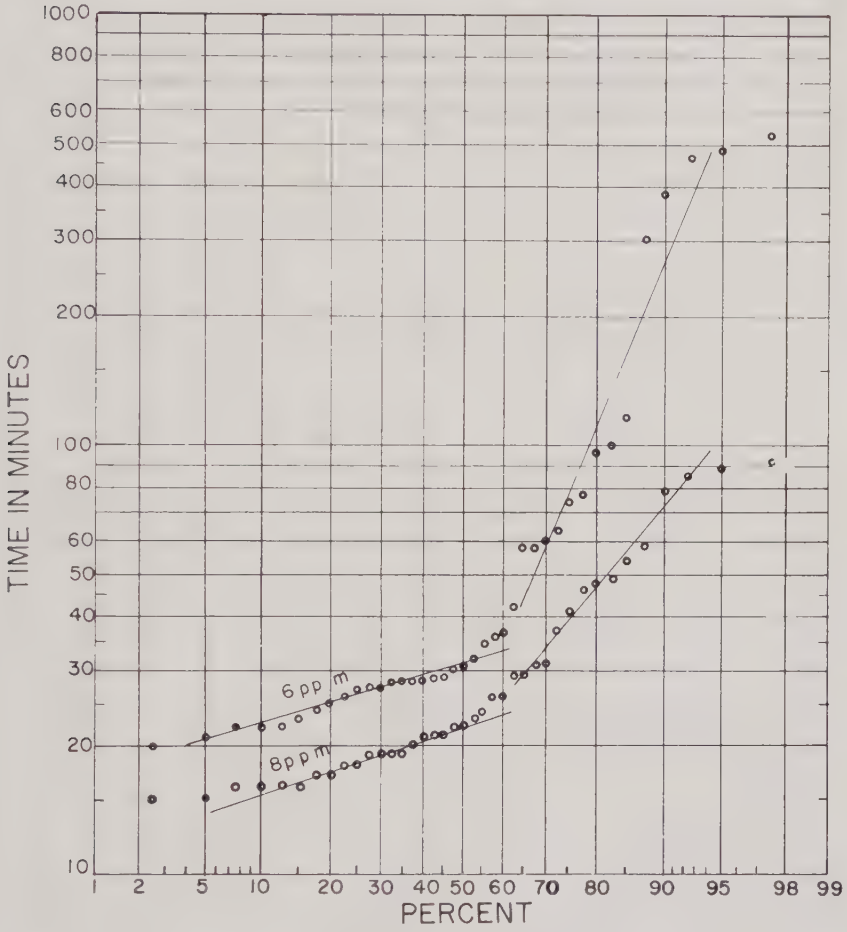

Figure 1. Slopes of time against percentage of mortality for individual times for death at two concentrations of 50W Sevin.

time, provided l-naphthol was of lesser toxicity. To test this, 256 milligrams of 50W Sevin were hydrolyzed to l-naphthol in alcoholic potassium hydroxide, the alcohol was distilled off and the excess hydroxide was neutralized with N/10 hydrochloric acid. The resulting solution was made up to 16 liters, representing an 8 ppm solution in terms of the original Sevin. A similar weight of 50W Sevin was slurried and made up to 16 liters. To each solution were added 10 fingerling brown trout that had been acclimatized to the experimental temperature of 60° F. and had been unfed for 3 days. The time for mortality of each individual fish was noted. The results are presented in Table 2.

As the central part of the data for the hydrolyzed derivative produced an entirely different slope of toxicity than that for Sevin, the derivative

Table 2. Comparison of 50W Sevin as Active Ingredient and after Hydrolysis to 1-naphthol

Item	As active ingredient	After hydrolysis
Number of fish	10	10
Average length (millimeters)	48.3	43.5
Concentration in ppm (as Sevin)	8	8
Range of time for death (minutes)	15–59	54–209
Range of central 60 per cent (minutes)	19–31	102–146
Logarithmic probability$_{50}$ (minutes)*	22	124

* Represents death.

can be assumed to be significantly different without other tests for significance. Hydrolysis produces a substance far less toxic than the original powder.

A replicate of this experiment showed a similar relationship. The replicate did not conform to the recommended procedure, in that the fish had been fed during the preceding 24 hours. Feeding appeared to slightly increase the toxicity of Sevin, but it had little effect on the toxicity of the 1-naphthol. More specific presentation of the results from the replicate will not be made.

If hydrolysis over short periods of time at the pH of the Rome Hatchery springwater produces appreciable 1-naphthol, the lessened toxicity would result in slower mortality and a steeper slope on logarithmic probability paper. Rate of hydrolysis would be dependent upon the concentration, pH, temperature and time.

Two 8 ppm solutions were prepared using 99T Sevin dissolved in acetone and made up to 16 liters. In the first, 10 fish were added immediately. The other was set aside for 1 hour and 40 minutes. Both were continuously aerated. Rapid mortality in the first solution appeared to involve only the first mode of toxicity, except for one fish. It was upright at the end of 30 minutes and appeared to have entered the second phase. A fresh solution was made up and this fish was transferred to it. Death was delayed for an additional 62 minutes. This appeared to confirm that the delayed mortality was not associated with reduced toxicity of the solution. After 1 hour and 40 minutes of aeration, 10 fish were added to the second solution. Mortality occurred at a slightly more rapid rate and all 10 fish died apparently as a result of the first mode of toxicity. The data are presented in Table 3.

The difference between the means was not significant at the 5 per

Table 3. Comparative Effect of Immediate and Delayed Use of Sevin Solutions at 60° F.

Item	Fish added immediately	Fish added after 100 minutes
Number of fish	10	10
Average length (millimeters)	34.2	35.5
Concentration in ppm (active)	8	8
Range of time for death (minutes)	14–92§	12-24
Logarithmic probability$_{50}$ (minutes)*	18	15
Mean logarithm (mode 1)	1.25310 (17.8 minutes)	1.19153 (15.5 minutes)
Comparison	$t=1.47$, d.f. 17	

* Represents death.
§ Fish removed to fresh solution after 30 minutes.

cent level. Hence, it was assumed that no significant hydrolysis and change in toxicity occurred during the period before use of the second solution. Since the solution was of an apparently slightly increased toxicity, even if it had reached the level of significance it would have had little importance in relation to a decrease of toxicity with time which was under study.

This seems to confirm the presence of bimodal toxicity and suggests that it is the result of some physiological reaction. It does not indicate whether it is caused by increased effectiveness of a detoxifying reaction resulting from exposure to the chemical or by inhibited intake of the chemical.

STATISTICAL PROCEDURE

Determination of a bimodal toxicity for Sevin introduced problems in handling the data, both in presentation and in comparison, for the three preparations of the product tested. Computation of logarithmic means would not be valid for comparing different preparations unless they were calculated for the same mode. Since the transition point between modes varied with the concentration, a procedure had to be developed to determine the time at which 50 per cent mortality occurred. Although the arithmetic median might have been used, individual variation and inclusion of aberrant fish could result in appreciable error in this statistic. A method of approximation which would average out some error seemed preferable. It was decided to break the combined data for each concentration into deciles, plotting the average time for

the decile at the average percentage on logarithmic probability paper. A graphical derivation of the logarithmic probability$_{50}$ could then be used as the time for 50 per cent mortality. Where the mode extended through 50 per cent more weight was given to those points that approached that percentage in establishing the straight line. In the few instances where the transition occurred between the 40+ and 50+ per cent plots, the intersection of the line connecting these two points with the 50 per cent line was considered to represent 50 per cent mortality.

Comparisons of the difference of the logarithmic means of the modes for similar concentrations were made by the *t*-test (Snedecor, 1956) to determine if they were statistically significant. Based on this test it was decided whether the preparations could be combined in one toxicity curve or would require separate presentation. Where a sufficient number of fish fell within both modes for a concentration, both were compared. This method of treatment is based on the assumption that, if no significant variation is found in the means for the modes intersecting the 50 per cent mortality point, it can be assumed that there would be no significant variation in the logarithmic probability$_{50}$ within those modes.

Variation in toxicity in relation to size or length of the fish was evident in much of the data. An approximation of this effect was made by separating the fish in each mode into those lying above and below the average length for the mode. New averages of length were computed as were the mean logarithms for time. These figures were used to compute a per cent-per-millimeter effect for size. Data for all modes were combined into a weighted average involving the number of fish in each mode and based on computations for 682 fish. This resulted in a figure of 0.4122 per cent per millimeter. The original mean logarithms for time for death for the modes of similar preparations were computed, and a comparison of the mean logarithms for time for death based on correction of the individual data to a fish length of 44 millimeters is also presented. The latter is believed to provide a more valid comparison and was used in arriving at a decision to combine the preparations. A fish length of 44 millimeters was chosen for comparison as this fell within, or relatively close to, the size range for each concentration.

COMPARISON OF 85P MICRONIZED SEVIN IN OIL AND WATER SUSPENSIONS

Using a fuel oil suspension of the 85% micronized Sevin prepared for use in spraying at Oneonta (N.Y.) in 1959, a solution of 16 ppm (active ingredient) was made up in 16 liters of Rome Hatchery springwater and thoroughly mixed for 5 minutes before the addition of brown trout fingerlings. A similar solution of the powder in aquaeous suspension was prepared by slurrying the powder with a small quantity of water

and making up to 16 liters. Also, since a reduction of toxicity from standing in the fuel oil solution for about a year was possible, a rough check on the suspended material was made. Part of it was filtered, washed four times with benzene to remove the fuel and paraffin oils, and dried. A measured quantity was then used to prepare an additional 16 ppm solution. A summary of the results appears in Table 4.

The extremely reduced toxicity of the oil suspension in water, indicates that oil greatly reduces the toxicity to fish, apparently by coating the particles of the active ingredient so that its solubility is greatly reduced. While there was an indication of higher toxicity in the original powder than in the material present in the oil, two factors may have contributed to this condition. The larger average size of the fish used

Table 4. Comparative Toxicity of 85P Micronized Sevin in Oil Suspension, after Removal of Oil and as Original Powder*

Item	In oil suspension	After removal of oil	As original powder
Number of fish	9	10	10
Average length (millimeters)	46.7	51.9	47.6
Range of length (millimeters)	34–54	40–56	37–54
Logarithmic probability$_{50}$ (minutes)	477	17.7	14.8

* All as 16 ppm active ingredient.

in the Sevin recovered from the oil suspension would result in slightly lowered toxicity. Correction for size was made by adjusting the individual times for death in both sets of data to a length of 47 millimeters. Comparison of the log means for mode 1, which included all but one fish, gave a t-value of 2.17 (d.f.=17). This value slightly exceeds the 5 per cent level for significance.

Pyrophyllite is frequently used as a filler in this type of preparation. It would not be expected to be soluble in either oil or benzene. If the solubility of Sevin in fuel oil is similar to that reported in petroleum distillate, the long contact with fuel oil could be expected to have reduced the concentration of the suspended material to about 78 per cent. Reference of the reconstituted powder solution to the toxicity curve for 99T-85P Sevin, after placing the time on an equivalent size basis, indicated the concentration to have been about 11 ppm. The powder would then have represented about a 58 per cent content of Sevin. Since the benzene would have removed some Sevin in the four washes used, it does not appear that the toxicity was greatly affected by standing in the solution for a year.

COMPARISON OF STATIC SOLUTIONS WITH FLOW-THROUGH SOLUTIONS

Toxicity of static solutions was compared with that of solutions having a flow-through of 8 liters per hour. Comparisons were made for concentrations of 16, 8 and 6 ppm of 50W Sevin, using 10 fingerling brown trout in each solution. The original solutions were made up to 16 liters, using Rome Hatchery springwater as the vehicle. With flow-through solutions, the fresh solution filled the jar to 20 liters, and thereafter overflow took place at the rate of admittance. The data are summarized in Table 5.

For the 16 and 6 ppm concentrations, the differences in length of the fish used in the two solutions were too wide to lend confidence in the results without adjustment for size. An increase in length reduces the apparent toxicity. Therefore, the times for death of the individual fish were recalculated according to a length of 44 millimeters based on the average effect for increase or decrease in length. These values are designated "calculated" in the table. For the 8 ppm concentration, the difference in length was so small that recalculation was not considered necessary.

None of the comparisons gave a *t*-value indicating significance. The numbers in the 6 ppm solution were small, since comparison had to be made in two modes rather than one. However, none approached significance closely enough to suggest that the results might be different with a reasonable increase in numbers. For this reason, the remainder of the studies were conducted in static solutions.

TOXICITY OF 50W SEVIN IN HARD AND IN SOFT WATER

Rome Hatchery springwater has an M.O. alkalinity about median for this State (average 100 ppm) with a pH ranging from 7.4 to 8.1 (average about 7.5 or 7.6). Woodhull Creek water is extremely soft (alkalinity from 6.0 to occasionally as high as 12.0 ppm). The pH ranges from 5.86 to about 6.85 after aeration. A complete analysis of its composition was given by Burdick *et al.* (1955). The pH after aeration in the study reported here was 6.85. An 8 ppm static solution of 50W Sevin in Woodhull Creek water was compared with the static solution at the same concentration in hatchery springwater as reported in Table 5. The results for 16-liter solutions are shown in Table 6.

A significant difference, below the 2.5 per cent level, was found for the mode 1 toxicity of these waters. Henderson *et al.* (1960) reported a lower toxicity of Sevin in soft waters with respect to the fathead minnow. In the present study Sevin was less toxic to brown trout in the soft, acid Woodhull Creek water than it was in the harder springwater with the pH on the alkaline side of neutrality. It confirms for this species

TABLE 5. COMPARATIVE TOXICITY OF SEVIN IN STATIC AND FLOW-THROUGH SOLUTIONS

Item	Static	Flow-through *
16.0 ppm concentration		
Number of fish	10	10
Average length (millimeters)		
Actual	45.2	32.4
Adjusted	44	44
Range of time for death (minutes)		
Actual	14 –37	14 –34
Calculated	13.4–37.1	15.4–37.1
Antilog of logarithmic probability$_{50}$ (minutes)		
Actual	17.1	17.4
Calculated	17.4	19.6
Mean logarithm (mode 1)		
Actual	1.29971 (19.9 minutes)	1.27104 (18.7 minutes)
Calculated	1.29171 (19.6 minutes)	1.33127 (21.4 minutes)
Comparison		
Actual	t=0.47, d.f. 18	
Calculated	t=1.02, d.f. 18	
8.0 ppm concentration		
Number of fish	10	10
Average length (millimeters)	49.1	48.9
Range of time for death (minutes)	17–72	16–808
Antilog of logarithmic probability$_{50}$ (minutes)	21.6	22.7
Mean logarithm (mode 1)	1.32036 (20.9 minutes)	1.35330 (22.6 minutes)
Comparison	t=0.69, d.f. 15	
6.0 ppm concentration		
Number of fish	10	10
Average length (millimeters)		
Actual	50.0	33.7
Adjusted	44	44
Range of time for death (minutes)		
Actual	22 –484	25 –694
Calculated	23.2 331	28.9–959
Antilog of logarithmic probability$_{50}$ (minutes)		
Actual	47.5	45.3
Calculated	43.5	46.7
Mean logarithm (mode 1)		
Actual	1.49084 (31.0 minutes)	1.50596 (32.1 minutes)
Calculated	1.5144 (32.7 minutes)	1.57117 (37.3 minutes)
Comparison (mode 1)		
Actual	t=0.18, d.f. 8	
Calculated	t=0.67, d.f. 9	
Mean logarithm (mode 2)		
Actual	2.20121 (159 minutes)	2.41668 (260 minutes)
Calculated	2.21753 (165 minutes)	2.51340 (326 minutes)
Comparison (mode 2)		
Actual	t=0.78, d.f. 8	
Calculated	t=0.99, d.f. 7	

* At 8 liters per hour.

Table 6. Comparative Toxicity of 50W Sevin at a Concentration of 8 ppm in Medium Hard and Soft Waters

Item	Medium hard water *	Soft water *
Number of fish	10	10
Average length (millimeters)	49.1	49
Range of time for death (minutes)	17–72	21–91
Logarithmic probability$_{50}$ (minutes)	21.6	28.0
Mean logarithm (mode 1)	1.32036 (20.9 minutes)	1.40373 (25.3 minutes)
Comparison	t=2.60, d.f. 13	

* Static solution.

the findings on the fathead minnow. It might indicate an interaction between Sevin and the components of the water rather than a physiological reaction of the fish to this type of water which results in a lowered effect of the Sevin contained in it.

EFFECT OF TEMPERATURE ON THE TOXICITY OF SEVIN

The toxicity of 50W Sevin in 8 ppm solutions (active ingredient) was tested with brown trout fingerlings at four temperatures. Two solutions were used at each temperature with 10 fish to each solution. The mean lengths of the fish used at the different temperatures varied considerably. Based on the average effect for increase in size, the times for death at three of the temperatures were adjusted individually to a fish length of 45.7 millimeters which was equal to the mean length of the

Table 7. Comparative Effect of Temperature on Toxicity of 50W Sevin at a Concentration of 8 ppm in Rome Hatchery Springwater

Temperature (degrees F.)	Number of fish	Length (millimeters)		Range of time for death (minutes)	Antilog of logarithmic probability$_{50}$ (minutes)	
		Range	Mean		Actual	After adjustment to 45.7 millimeters
48.6	20	35–44	37.6	39–2,710	860.0	1,060.0
55.0	20	33–42	38.8	22– 132	34.0	38.2
60.0	20	31–52	39.2	15– 273	23.0	26.2
65.5	20	38–55	45.7	13– 381	17.4	..

largest size group. Corrected values for logarithmic probability$_{50}$ based on these times were then graphically estimated. The data are presented in Table 7.

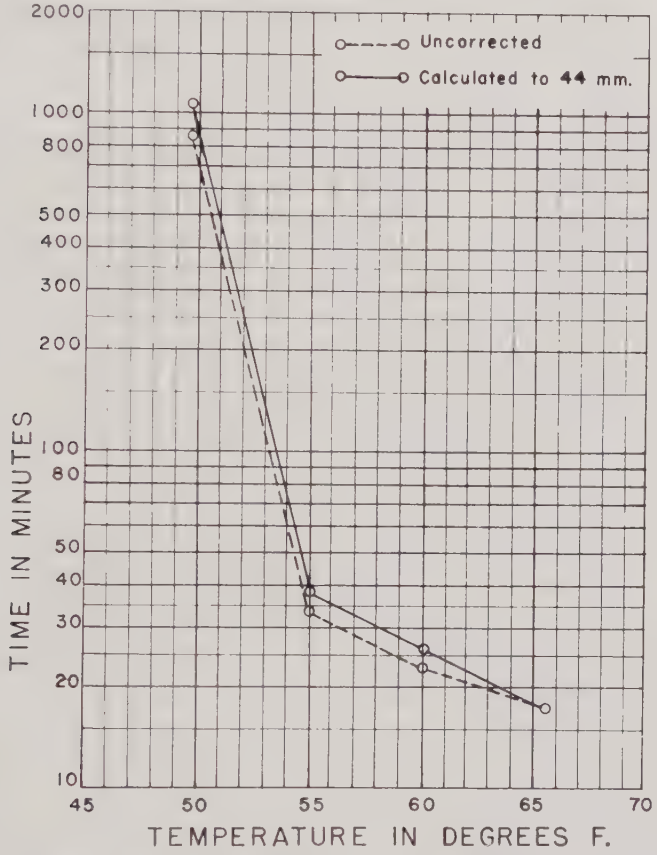

Figure 2. Effect of temperature on the toxicity of 50W Sevin in an 8 ppm solution based on uncorrected data and after calculation for a fish length of 45.7 millimeters.

Graphic presentation of the slope for the effect of temperature appears in Figure 2. Both the corrected and uncorrected data are plotted. The logarithmic probability$_{50}$ fell in mode 1 for temperatures 65.5°, 60°, and 55° F. At the 48.6° F. temperature it fell in mode 2. The three values for logarithmic probability$_{50}$ within mode 1 appear to form a straight line after correction. The equation for this line is

$$Y = 3.37037 - 0.03252X$$

where,

Y = logarithm of time for logarithmic probability$_{50}$
X = temperature in degrees Fahrenheit.

If this relationship is valid, the slope for the effect of temperature at other concentrations would be essentially parallel within mode 1. An approximation could be made of probable mortality at higher temperatures from the mortality curve at 60° F., provided the reaction fell within mode 1. Greatly decreased toxicity would occur with entrance to mode 2. In this particular experiment this occurred at a temperature above 48.6° F.

COMPARISON OF THE TOXICITY OF THREE PREPARATIONS OF SEVIN

85P micronized, 99T (technical) and 50W (50% wettable powder) Sevin were available for this phase of the study. The 85P micronized form was from material prepared for use in gypsy moth spraying near Oneonta in 1959; only a small quantity was available and experimentation had to be limited. Comparisons were based upon the logarithmic means of the major modes which included, except in the 4 ppm concentration, the point of 50 per cent mortality. The *t*-test was used, and it was assumed that if there was no significant difference between the means of the different preparations there was no significant difference between their toxicities. Since variation in the size of the individual fish used would shift the location of the mean, the data were adjusted to a length of 44 millimeters using the average correction factor previously described, and a new logarithmic mean for time for death was calculated. At the two lowest concentrations, 2 and 1.5 ppm, most of the mortality occurred in mode 2. Some of the experiments were terminated before complete mortality had occurred. In addition, an increased rate of death was noted in some of the studies over extremely long time periods, believed ascribable to the interaction of non-volatile metabolic products. Determination of the logarithmic mean involved in these variations would result in an invalid figure and for this reason they were eliminated from the comparisons. The data for the three preparations are presented in Table 8. A general discussion of the testing procedure is included under the next topic.

Comparisons of the logarithmic means were made using the *t*-test for groups with different numbers of individuals as described by Snedecor (1956). To reduce the effect of size variation only corrected data were used. The 85P form tested significantly different (at the 5 per cent level) from 99T in only one of the eight concentrations compared, i.e., at 64 ppm. The 99T form tested significantly different from 50W in seven concentrations, and 85P tested significantly different from 50W in four concentrations. At the 64 ppm concentration, slight variation in determining the actual time of death and the variation caused by estimating time to the nearest minute could have resulted in either signifi-

cant or nonsignificant values. The data for 85P and 99T were combined in calculating toxicity curves. While the combined data for the modes are not presented in tabular form, comparison with those for 50W showed significance in seven of the eight concentrations. The only exception was the 64 ppm concentration.

TIME-CONCENTRATION TOXICITY CURVES FOR SEVIN

The bimodal distribution of the toxicity in some concentrations required a graphical determination of the logarithmic probability$_{50}$ at each concentration to approximate the time for 50 per cent mortality. Individual times for death were combined in deciles and averaged, and the average was plotted on logarithmic probability paper. Fitting the curve with the best straight line intersecting 50 per cent mortality was done by eye, using a transparent straightedge. Particular attention was given closeness of fit through the central part of the data. The logarithmic probability$_{50}$ was then read directly from the point of intersection. The computations were made using time for death uncorrected for fish size and after recalculating the individual times to a 44-millimeter length. Only times corrected to this length were used in preparing toxicity curves for the Sevin products.

A total of 315 fingerling brown trout ranging in length from 29 to 64 millimeters were used in the nine concentrations of 99T Sevin. The chemical was dissolved in acetone before adding to water. For the 85P preparation, 160 fish ranging in size from 37 to 60 millimeters were used. The product was slurried in a small amount of water before making up the solution. In the test solutions the number of fish ranged from 10 to 3 per 16 liters. These two preparations are combined in tabular presentation to show the number of fish, range of length, mean length, range of time for death and the antilogs of the values for logarithmic probability$_{50}$ at each concentration (Table 9). Included are the corresponding data for the 340 fish used in testing the 50W preparation. This was slurried in water before making up to 16 liters. It was found slightly less toxic in equivalent concentrations.

Plotting the deciles for the 2 and 1.5 ppm concentrations showed deviations from the straight line in the upper deciles. The slope indicated a progressively increased toxicity. It could not be ascribed to reduction in the oxygen content because the solutions were continuously aerated. The gradual increase suggested a similar increase in whatever was affecting the time for death. The effect occurred first in containers holding the largest number of fish. Buildup of nonvolatile metabolic products capable of affecting mortality seems the most likely explanation.

The intersection of the lines for time and 50 per cent mortality

Table 8. Logarithmic Means of Modes at Different Concentrations for Three Sevin Preparations

Concentration (ppm)	Mode	Number of fish	Length (millimeters)		Range of time for death (minutes)	Logarithmic mean					
						Actual			Calculated*		
			Range	Mean		Mean	Sum deviation^2	Antilog of logarithmic mean (minutes)	Mean	Sum deviation^2	Antilog of logarithmic mean (minutes)
85P micronized Sevin											
64	1	20	40–55	46.8	5– 11	0.88419	0.13977	7.7	0.87377	0.12987	7.5
32	1	20	37–55	46.4	7– 16	1.02537	0.14037	10.6	1.01498	0.13379	10.4
16	1	20	37–54	47.6	10– 20	1.15522	0.10837	14.3	1.13802	0.09956	13.7
8	1	18	37–59	46.4	16– 25	1.30748	0.04862	20.3	1.28557	0.07141	19.3
6	1	16	40–57	47.9	19– 34	1.40543	0.11868	25.4	1.38291	0.12611	24.2
4	1	10	44–59	49.0	23– 51	1.46847	0.09103	29.4	1.43439	0.12757	27.2
4	2	10	42–57	48.1	80– 853	2.36723	1.33334	233.0	2.30899	1.19456	204.0
3	2	15	41–54	46.8	80–2,697	2.48433	3.45961	305.0	3.45125	3.03393	283.0
99T Sevin											
64	1	30	31–54	41.0	5– 10	0.80768	0.19198	6.4	0.81690	0.17549	6.6
32	1	28	31–57	41.2	6– 16	0.97888	0.31750	9.5	0.98894	0.27443	9.8
16	1	36	31–54	40.3	9– 25	1.11967	0.54217	13.2	1.13546	0.47965	13.7
8	1	35	31–46	36.8	11– 35	1.22263	0.32418	16.7	1.25831	0.31388	18.1
6	1	23	35–57	41.6	17– 43	1.36941	0.18708	23.4	1.38188	0.17378	24.1
4	1	19	34–53	43.2	21– 43	1.47978	0.15675	30.2	1.48394	0.12157	30.5
4	2	11	30–50	42.0	55–1,494	2.28240	2.51835	192.0	2.30521	2.86970	202.0
3	2	35	35–51	42.3	55 5,542	2.40167	12.53760	252.0	2.41994	13.02676	263.0

50W Sevin

64	1	30	40–56	47.3	4- 14	0.89394	0.57476	7.8	0.88173	0.57165	7.6
32	1	26	42–57	49.2	8- 15	1.07009	0.11104	11.8	1.04675	0.12873	11.1
16	1	35	26–56	43.2	11– 23	1.20957	0.27641	16.2	1.21458	0.35467	16.4
8	1	30	29–54	44.4	15- 42	1.32458	0.40214	21.1	1.32391	0.46083	21.1
6	1	25	29–59	45.0	20- 42	1.43856	0.15660	27.5	1.43393	0.24822	27.2
4	1	16	36–60	44.5	23- 71	1.66360	0.28405	46.1	1.66034	0.31320	45.7
4	2	24	40–58	45.7	110–2,415	2.93471	2.59343	860.0	2.91358	2.75734	820.0
3	2	35	33–46	40.1	160–2,286	2.96988	2.56452	933.0	3.01690	2.59169	1,040.0

* To a standard fish length of 44 millimeters.

Table 9. Values of Logarithmic Probability$_{50}$ for 85P and 99T Sevin Combined and for 50W Sevin

Concentration (ppm)	Number of fish	Length (millimeters)		Range of time for death (minutes)	Antilog of logarithmic probability$_{50}$ (minutes)	
		Range	Mean		Actual	Calculated*
85P and 99T Sevin combined						
64	50	31–55	43.4	5– 11	6.8	7.0
32	50	31–57	43.5	6– 19	10.0	10.1
16	60	31–54	42.9	9– 50	13.5	13.6
8	60	31–59	40.7	11– 260	18.8	19.2
6	50	35–57	44.3	17– 456	26.1	25.4
4	50	30–59	45.5	21– 1,494	39.3	38.5
3	60	35–54	44.1	23– 5,542	133.0	132.0
2	60	29–60	43.9	36–>6,045§	1,210.0	1,240.0
1.5	35	33–64	46.1	36– 4,049	3,100.0†	2,800.0†
50W Sevin						
64	30	40–56	47.3	4– 14	7.7	7.6
32	30	42–57	49.1	8– 27	11.8	11.3
16	40	26–56	43.2	11– 37	16.7	17.2
8	40	29–54	43.3	15– 273	23.3	23.5
6	40	29–59	44.9	20– 694	31.4	33.2
4	40	36–60	45.2	23– 2,415	240.0	220.0
3	40	33–46	40.6	30– 2,286	826.0	970.0
2	40	35–57	45.7	39–>5,850§	1,820.0‡	1,710.0‡
1.5	40	30–46§	38.7	366–>8,564§	3,550.0	4,200.0

* To a standard fish length of 44 millimeters.
§ Terminated while some fish were still alive and unmeasured.
† Projected from 2nd through 5th decile.
‡ Projection based on first three deciles.

was significantly affected in only two of the four concentrations. In the 2 ppm solutions of 50W, deviation began in the fourth decile. Projection from the first three deciles was used to establish the approximate time of 50 per cent mortality, although it was assumed to be subject to rather high error. In the 1.5 ppm 85P-99T combination, deviation started in the sixth decile, and the 50 per cent point was established by projection from the first five deciles. The other two concentrations both intercepted the line for 50 per cent mortality before departing from an approximately straight line.

Based on calculation to a fish length of 44 millimeters, the time-concentration curves for toxicity are presented in Figure 3. The two modes of toxicity resulted in separating each of the curves into two different slopes. The break occurred near the transition point between one mode and the other. Usually a logarithmic plot of time against concentration has some curvature. In this case, it is probably slight in each

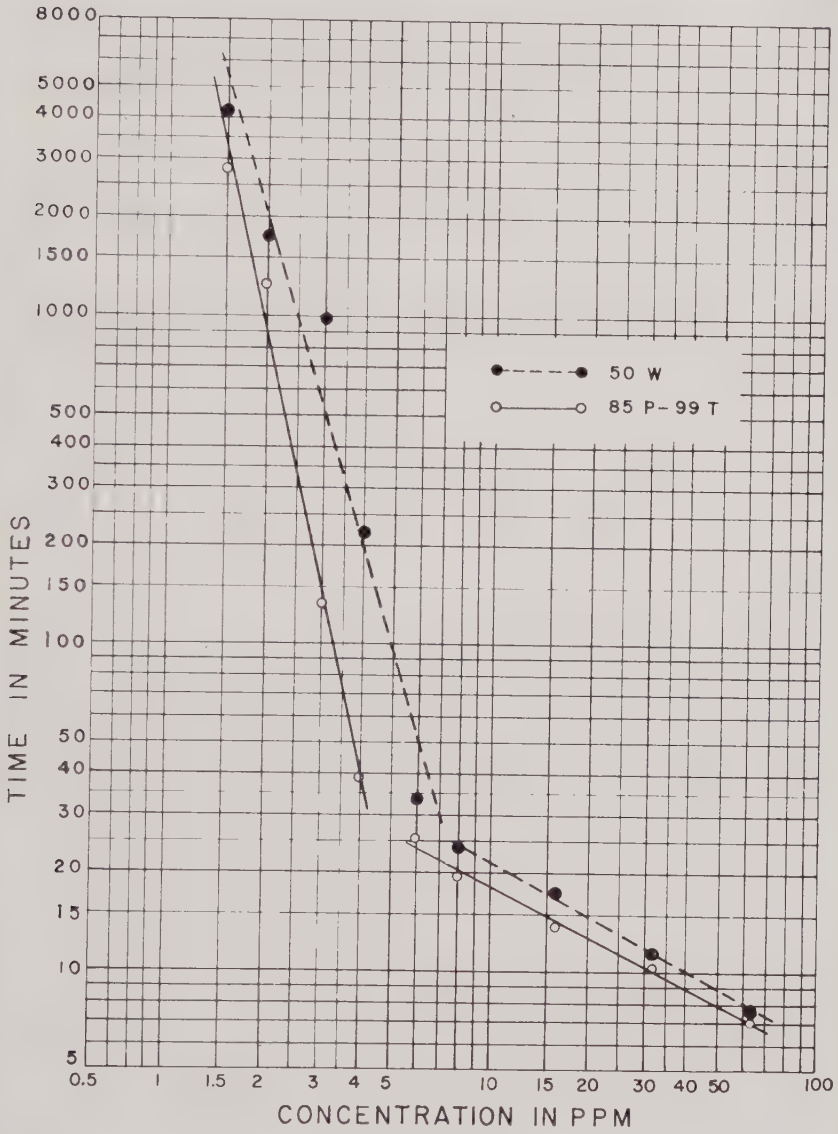

Figure 3. Toxicity curves for 50W and 85P-99T Sevin, based on antilogs of log probability$_{50}$, after calculating individual times for a fish length of 44 millimeters using an average correction factor.

mode but hidden by the variability of the data. The two portions of the curve falling in different modes have been fitted by straight lines by the method of least squares (Bliss, 1952). Transition from one mode to the other was indicated to occur between 6 and 8 ppm in the 50W Sevin and between 4 and 6 ppm in the 85P-99T combination.

It is improbable that toxicity to brown trout would be a factor at the usual application rate of 1 to 1.25 pounds, per acre. Attainment of toxic level of 1.5 ppm would not be likely in any application to water averaging over 4 inches in depth.

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SOME OBSERVATIONS ON THE ECOLOGY OF THE MOURNING DOVE IN NEW YORK[1]

Philip N. Lehner Research Assistant
New York Cooperative Wildlife Research Unit
at Cornell University[2]

ABSTRACT

Observations on the ecology of the mourning dove, based largely on 180 speciments collected from March through October in 1963, were made in Tompkins County (N.Y.). Data on their age, sex, size, food habits and breeding condition were recorded. Information on range conditions and distribution and abundance were also gathered. Available records indicate a slightly rising population, but no section of the State supports populations comparable to those found in the better habitats in other parts of the United States. Doves were closely associated with farmland, particularly that devoted to small grains the acreage of which is decreasing. The chief foods eaten were wheat, corn, buckwheat, yellow bristlegrass and ragweed in that order. Food consumption was greatest from 6 p.m. to sundown. Nesting was at its height in early May, but it occurred throughout the summer and continued into September after many doves had migrated. Late nesting, early migration and a low wintering population are unfavorable to the prospect of dove hunting in New York.

In the last 15 years the mourning dove (*Zenaidura macroura*) has become an important game bird in many parts of the country. At present 31 states have an open season on doves, and the total kill in these states may exceed 25 million. As of 1961, research on the mourning dove had been carried on in 37 states 13 of which do not have a dove season. Within the eastern management unit, as described by Kiel (1959a), research has been concentrated in the South, Southeast, and Midwest. In the Northeast, some research has been conducted in Maine (Powell, 1949), Massachusetts (Austin, 1951), and Pennsylvania (Howarth, 1954; Sheldon, 1957; Schemnitz, 1964).

The present study, made in 1962-63, was confined to Tompkins County in the central part of New York State. Data was based largely on 180 doves collected from March through October in 1963 (one other was collected in October 1962). Since the northern two-thirds of the county contains the better dove habitat, most doves were collected in that area (Figure 1). Although the overwintering population in the State appears to be increasing yearly, it is not at a level which would allow extensive collecting. Consequently, most collections were limited to the spring, summer and early fall months (Table 1). Data were

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[1] Derived from a Master's thesis submitted to the Graduate School, Cornell University. Appreciation is extended to Dr. D. Q. Thompson for direction and advice during the entire study. Mr. Olan W. Dillon of the U.S. Soil Conservation Service provided assistance on food habits examinations. Mr. Thomas M. Beetle of the Cornell Biometrics Unit gave valuable advice on statistical analysis.

[2] New York State Conservation Department, Cornell University, U.S. Bureau Sport Fisheries and Wildlife, and Wildlife Management Institute cooperating.

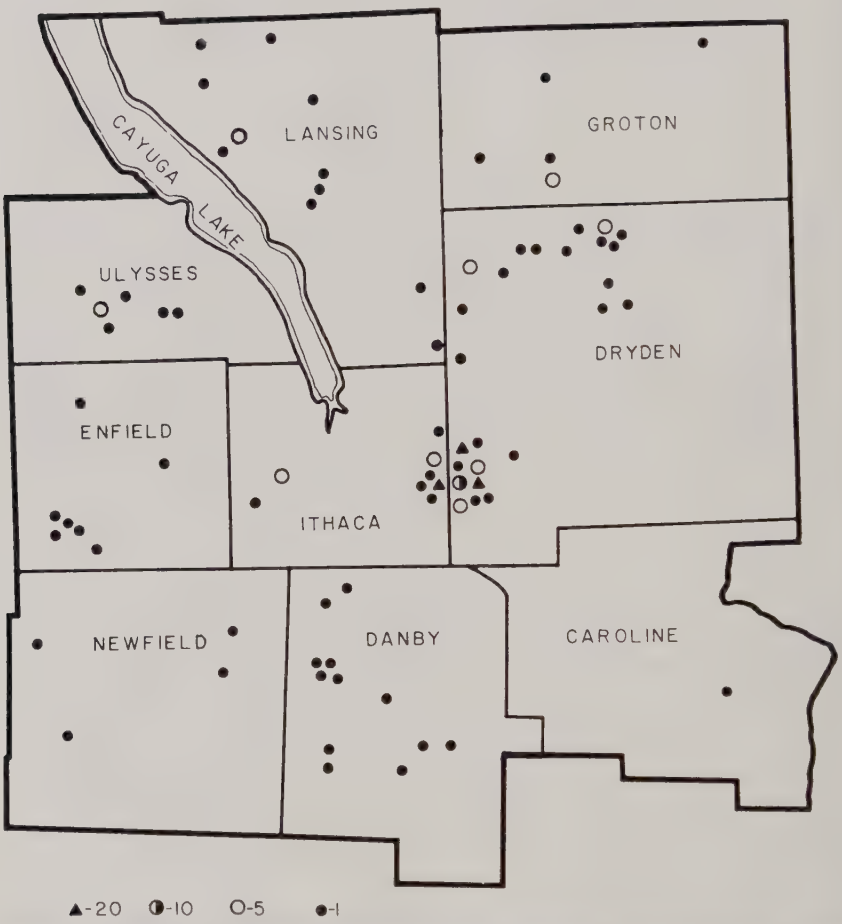

Figure 1. Map of Tompkins County showing locations where mourning doves were collected and number taken at each.

applied to three major fields of study: morphological measurements, food habits, and breeding.

MATERIALS AND METHODS

When a dove was collected, a tag was immediately attached to the leg and the following data were recorded on it: location, date, time, sex and age. Sex and age were determined by the methods described by Petrides (1950) and Pearson and Moore (1940). Total length, tail length and wing length were also recorded, together with the stage of development of the crop gland for adults, i.e., not developed, slightly developed, developed or well developed. The crop contents were removed and placed in a coin envelope for later analysis.

Wings of juvenile specimens were removed and later aged according to feather molt as described by Pearson and Moore (1940). The age criteria used were those of Hanson and Kossack (1963). It was felt that these criteria were probably more representative of conditions in New York than the criteria described by Swank (1955) for Texas, Russell (1955) for Kentucky, or Jenkins (1955) for Georgia. When two feathers were found to be in molt at the same time, both were used as age criteria. In most cases the ages determined from the two feathers were the same or differed by only a few days. When differences were found, the mean age was taken. When a wing was found in which molt had not yet begun, the bird was considered to have been 21 days old; this is the mean of the age at which young doves leave the nest (14 days) and that at which the first primary is dropped (28 days). Since only 13 juveniles fell in this age bracket, the discrepancy caused by using this mean was not considered important.

Crop contents were analyzed by the methods described by Davison (1940). Contents from each crop were separated by species and measured by volume in graduated cylinders. Contents were measured dry, and the volume was estimated visually in cubic centimeters. Davison suggested that crops should not be used in which less than 2 cubic centimeters of food occurs. In this study all crops were used. Those foods that occurred in amounts greater than 0.1 cubic centimeter were recorded quantitatively; those occurring in amounts less than that were recorded as "traces". Data for all crops were combined by the "aggregate percentage" method described by Martin *et al.* (1946).

RESULTS AND DISCUSSION

The data from specimens collected and information from other sources are summarized with respect to the distribution and abundance, biology and habits of the species.

Distribution and Abundance

New York does not have a dove season. Statewide sight records published in the Kingbird[3] from 1951 to 1963 indicate an over-all increase in the dove population in the last 12 years. Coo-call count data reported by the U.S. Fish and Wildlife Service indicate a slight, but continuous, fluctuation in the breeding population index over the past 7 years.

Eaton (1923) and Spiker (1935) recorded the distribution of the mourning dove in New York during earlier periods. Since 1935, changes in land use have had an effect on the amount of good dove habitat available. The acreage in small grains has declined. The proportion of farm acreage in small grains has remained about the same, but the num-

[3] Quarterly organ of the Federation of New York State Bird Clubs, Inc.

Table 1. Monthly Distribution of Doves Collected in Tompkins County*

Month	Adult		Juvenile	Total	Per cent juvenile
	Male	Female			
March					
1–15	..	..	..	..	....
16–31	1	..	..	1	....
April					
1–15	1	1	..	2	....
16–30	..	1	.	1	...
May					
1–15	4	2	..	6	....
16–31	1	1	..	2	....
June					
1–15	4	..	5	9	55.6
16–30	4	8	8	20	40.0
July					
1–15	1	3	12	16	75.0
16–31	13	5	12	30	40.0
August					
1–15	2	6	11	19	57.9
16–31	12	16	18	46	39.1
September					
1–15	2	4	3	9	33.3
16–30	4	5	9	18	50.0
October					
1–15	1	1	..	2	....
16–31	..	..	..	..	....
Total	50	53	78	181	43.1

* Except for an adult female taken October 8, 1962, all were collected in 1963.

ber of small farms has decreased and these crops are now concentrated on the larger commercial farms. The mourning dove occurs throughout the State in all but the heavily forested areas, but no section supports populations comparable to those found in the better habitat in other parts of the United States.

The only collection made in 1962 was an adult female taken on October 8. The next collection was not made until March 1963. From March to October (1963) the numbers collected each half month (Table 1) reflected the general density of doves during those periods. The peak month was August when nesting reached a temporary low and both juveniles and adults were found in greater abundance throughout the day. When fledglings first leave the nest they are very naive and vulnerable. At this time, the juveniles can be easily distinguished by their smaller size, mottled coloration, and naive behavior.

The percentage of juveniles was greatest in July, indicating that a peak in nesting had recently occurred. Quay (1954) found the juvenile population in North Carolina to peak in August. Tomlinsen *et al.*

(1960), in Missouri found the percentage of juveniles in their trapped sample to be greatest in September. They suggested that the steady increase from June through September may have been due, in part, to an influx of northern-reared juveniles. Hanson and Kossack (1963) suggested that, " . . . there appears to be a gradual drift southward of immature doves from their birthplace while nesting is still under way". Further banding in New York should reveal whether this is a primary cause for the decrease in juveniles in the population after July. Table 1 shows that there was still a substantial number of juveniles present through September, and late nesting is suggested as the cause.

Overwintering in New York is increasingly prevalent. Christmas "bird-counts" published in the Kingbird since 1951 have shown fluctuations in the number of mourning doves sighted but a general upward trend in abundance. All doves observed by or reported to the author during the winter were either feeding in cornfields, around corn bins, at bird feeders, or loafing on telephone wires. The largest flock known to have been overwintering in the county during 1963-64 was one of 32 birds. Inspection of a cornfield frequented by this flock revealed that deer had uncovered many ears of corn and scattered kernels on which both doves and pheasants were feeding. Because the food source was generally known, and the population was small, no doves were collected at that time.

Morphological Measurements

Sexing and aging were done in the field by plumage and in the laboratory by internal inspection. It was found that a high degree of accuracy was attained using only the plumage. However, when some juveniles had molted at least their eighth primary and their eighth, ninth and tenth primary coverts, bursal inspection (Wight, 1956) was necessary.

For adults in the sample examined the sex ratio was 94.5 males per 100 females which agrees with the findings of numerous investigators. Adult males, adult females, and juveniles showed consistent and nearly proportional differences in the following measurements: weight, total length, and wing length (Figure 2). The overlap of two standard deviations indicates that the means were not significantly different. However, one standard deviation from the mean for each adult female measurement is consistently less than the mean for the adult male, except in wing length where one standard deviation equals the mean for the male.

Quay (1951) stated that doves in North Carolina reach a peak in weight in January-February and steadily decrease through the summer and into the fall. In the present study, adults were collected from March through October, the greatest number being taken in July and August.

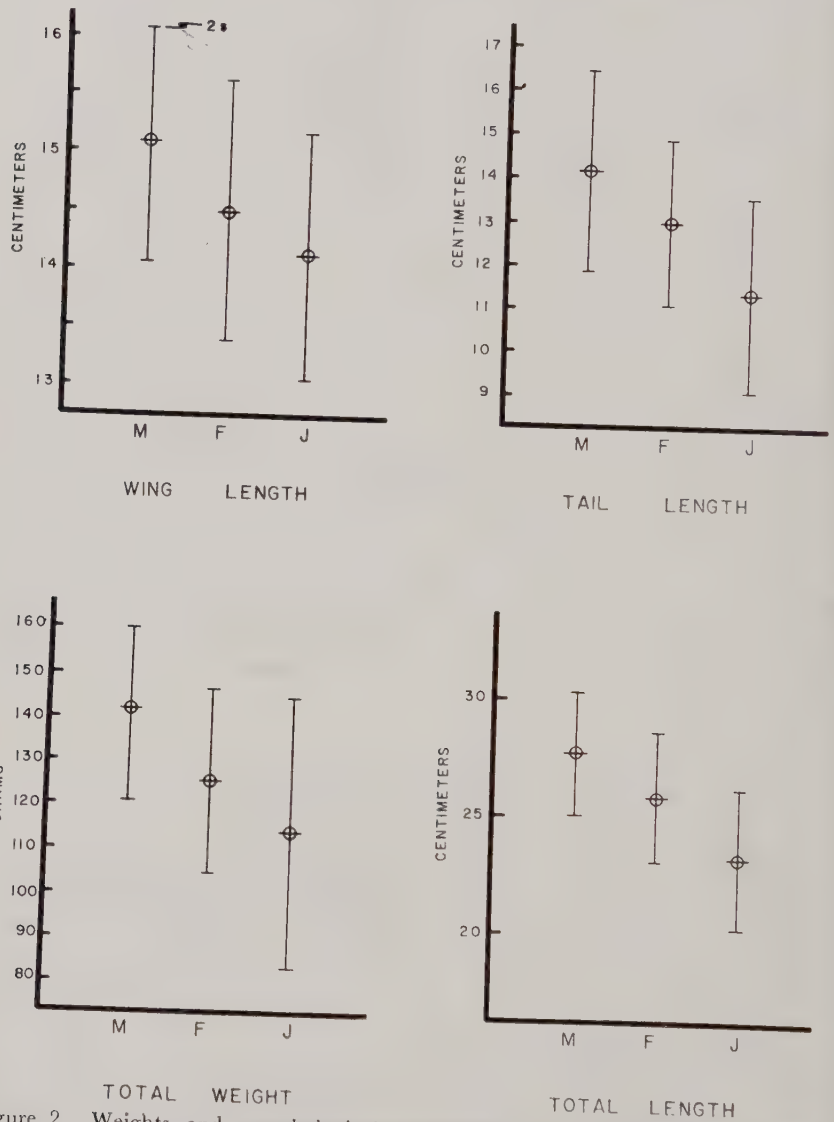

Figure 2. Weights and morphological measurements of 181 mourning doves examined.

The mean weights are summarized in Table 2 together with data for four other studies in the East and Midwest. The weights for both adult males and females from New York were slightly higher than those recorded in Alabama, Illinois, North Carolina and Virginia. They were slightly less than the maximum weights recorded by Quay during January and February. Since this "maximum weight" period was not represented by a single specimen in the present study, it may be assumed that

TABLE 2. MEAN WEIGHTS OF ADULT MOURNING DOVES

State	Year	Sex	Weight (grams)	Authority
Alabama	1941	both	125*	Moore and Pearson (1941)
Illinois	.....	male female	122.6 114.6	Hanson and Kossack (1963)
North Carolina	1940–42	male female	133* 124*	Quay (1951)
New York	1963	male female	141.4 126.6	(this study)
Virginia	1951	both	131.9	Sprunt (1957)

*Approximate.

weights of doves during that period would be greater than those recorded by Quay. It seems quite possible that, as doves increase in number in this area and become less migratory, "Bergmann's Rule" may apply, i.e., doves frequenting the more northern latitudes will be found to average larger than those in southern areas.

FOOD HABITS

Collections were unevenly scattered throughout Tompkins County (Figure 1). The northern two-thirds of the county contains the better dove habitat. This is an area of extensive agriculture, both commercial and small farm operations, and the principal crop is small grains. The southern third of the county is characterized by steep topography, much forested land and little agriculture; scattered dairy farms and small grains grown for feed provide some favorable habitat. The location of collections, in part, reflected these habitat differences.

There were two main reasons for the heavy concentration of collections in the center of the county: (1) this area, in the vicinity of the Ithaca Game Farm, provided ideal habitat for the mourning dove with its small grain agriculture, coniferous plantation, gravel roads, and meandering stream; (2) because of the large number of doves in the area and its close proximity to the Cornell University campus, it provided a source of specimens when only a short time could be spent in the field.

In order to determine whether there was a bias in the food habits data due to the unequal distribution of collections throughout the county, the 94 specimens from the central area were compared with the other 87 specimens. A "Student's" *t*-test (Snedecor, 1940) was run using the seven foods found most frequently in all the crops examined (see Table 4). The results (Table 3) indicated little bias. Only the values for corn

Table 3. Comparison, With Respect to Foods Eaten, of Doves (94) Collected in Vicinity of Ithaca Game Farm and Those (87) Collected Elsewhere in Tompkins County

Food	F	$S_{\bar{d}}$	t	$t'_{.2}$
Wheat	1.02	6.63	0.55	....
Corn	1.28	5.48	1.62§	....
Buckwheat	1.13	5.10	0.73	....
Bristlegrass, yellow	2.36*	4.12	1.22	1.29
Ragweed, common	3.62*	2.10	0.68	1.29
Oats	2.11*	1.73	0.53	1.29
Mustard, black	1.12	1.73	0.03	....

* Significant at the .005 level.
§ Significant at the .20 level.

were significantly different at the .20 level of probability. This level was chosen rather than the usual .05 or .01 levels where the means could be quite different and still not cause the null-hypothesis of no significance to be rejected. The fact that percentages were used in the food habits determinations kept the variances very high. Even with arc sin transformation, individual observations ranged from 0 to 90. These large variances gave rise to small t-values and consequently made differences hard to detect. Because there was a significant difference between the two areas for only one food item, the data were combined.

The significant difference with respect to corn probably reflected a greater availability of corn in the Ithaca Game Farm area. Yellow bristlegrass (*Setaria lutescens*) came closest to showing significance among the remaining species. This plant was found in great abundance in recently harvested fields, especially cornfields. Common ragweed (*Ambrosia artemisiifolia*) and black mustard (*Brassica nigra*) were not found to invade recently harvested fields with nearly the vigor exhibited by yellow bristlegrass.

Analysis of crop contents for the 181 specimens examined are summarized in Table 4. The foods eaten consisted almost entirely of seeds. The 26 plant species represented in significant amounts were distributed by family as follows: nine in the grass family (Gramineae), six in the mustard family (Cruciferae), four in the buckwheat family (Polygonaceae), three in the pink family (Caryophyllaceae), one each in the composite (Compositae), crowfoot (Ranunculaceae), amaranth (Amaranthaceae), and legume (Leguminosae) families. Beckwith (1959) stated that the grass family has been found by most investigators to be

the most important food source for doves, comprising 40-75 per cent of the diet. He stated further that legumes comprise 3-15 per cent of the diet, spurges 5-8 per cent, ragweed 1-5 per cent, sedges 1.5-4 per cent, and pokeweed 0.2-7 per cent. The results of the present study correspond in general to the ranges suggested by Beckwith. Grasses comprised 70.7 per cent of the total diet, legumes 1.4 per cent, and ragweed 3.2 per cent. Spurges, sedges and pokeweed did not occur in significant amounts. Of the 181 crops analyzed 139 had foods in significant amounts, 26 contained only traces, and 16 were empty.

Wheat (*Triticum aestivum*) was the top ranking food item in both frequency of occurrence in crops and amount eaten. Based on Duncan's new multiple range test (Steel and Torrie, 1960), it was significantly different in volume from the other food items at the .05 level of probability. In 1963, five small grains were grown on 28,442 (approximately 9 per cent) of Tompkins County's 314,240 acres (Table 5). Only oats and corn exceeded wheat in acreage grown. All three were listed as "choice" dove foods by Davison and Sullivan (1963); however, wheat becomes available through harvest earlier, and because of its slow germination it remains available to doves longer.

Corn (*Zea mays*) ranked second in amount eaten, but the volume was not significantly different from that for buckwheat (*Fagopyrum esculentum*). Including both grain and sileage the acreage devoted to corn was greater than that to any other small grain in the county. It is not harvested until fall and does not contribute much to the dove's diet until winter and the following spring. Clean harvest methods and widespread replowing make much of the corn unavailable, but its extensive distribution and large seed size make it an important food.

Buckwheat ranked third in both frequency of occurrence and amount eaten. Although it occupied 3.10 per cent of the small grain acreage in the county, its large seed size and the frequency with which it was eaten accounted for its high rank. Davison and Sullivan (1963) did not test this particular species of buckwheat, but ranked *Fagopyrum sagittatum* as only "fair".

Yellow bristlegrass (*Setaria lutescens*) is an imporant dove food which ranked fourth in this study. Its aggregate percentage (9.9) was significantly different from those for the other food items, and it had the second highest frequency of occurrence. It is a common annual weed in waste and cultivated areas, dropping seeds from June to September which offer a steady supply of available dove food.

Common ragweed (*Ambrosia artemisiifolia*) ranked fifth both in frequency of occurrence and amount eaten, but it was not significantly different in aggregate percentage from any of the five species following it in Table 4. Ragweed is an annual weed of both cultivated and

Table 4. Relative Importance of Foods Identified in Crops of 181 Mourning Doves Collected in Tompkins County * §

Food†	Frequency of occurrence (per cent)	Aggregate percentage of volume	Duncan's new multiple range‡	Davison and Sullivan's classification
Wheat (*Triticum aestivum*)	44.2	35.6		choice
Corn (*Zea mays*)	26.5	22.1		choice
Buckwheat (*Fagopyrum esculentum*)	21.5	16.4		....
Bristlegrass, yellow (*Setaria lutescens*)	35.9	9.9		choice
Ragweed, common (*Ambrosia artemisiifolia*)	21.0	3.2		choice
Oat, common (*Avena sativa*)	6.1	1.9		choice
Mustard, black (*Brassica nigra*)	3.3	1.4		....
Clover (*Trifolium* sp.)	1.1	1.4		....
Amaranth, redroot (*Amaranthus retroflexus*)	7.2	1.2		choice
Charlock (*Brassica kaber*)	9.4	1.0		choice
Buttercup, Pennsylvania (*Ranunculus pensylvanicus*)	6.1	0.8	....	....
Radish, wild (*Raphanus raphanistrum*)	1.6	0.8	....	....
Wintercress, early (*Barbarea verna*)	2.8	0.7	....	....
Crabgrass, smooth (*Digitaria ischaemum*)	1.1	0.7	....	....
Campion, red (*Lychnis dioica*)	7.7	0.6	....	....
Campion, evening (*Lychnis alba*)	2.2	0.6	....	....
Cornbind, dullseed (*Polygonum convolvulus*)	7.7	0.3	....	....
Wintercress, bitter (*Barbarea vulgaris*)	9.9	0.2	....	....
Silene, nightflowering (*Silene noctiflora*)	8.3	0.2	....	....
Bermudagrass (*Cynodon dactylon*)	7.7	0.2	....	....
Sheep sorrel (*Rumex acetosella*)	7.2	0.2	....	uneaten

TABLE 4. (*concluded*)

Food†	Frequency of occurrence (per cent)	Aggregate percentage of volume	Duncan's new multiple range‡	Davison and Sullivan's classification
Ladysthumb, spotted (*Polygonum persicaria*)	8.8	0.1	....	....
Bristlegrass (*Setaria* spp.)	7.2	0.1	....	....
Pepperweed, field (*Lepidium campestre*)	5.5	0.1	....	....
Panicum (*Panicum* spp.)	3.3	0.1	....	choice
Velvetgrass, common (*Holcus lanatus*)	0.6	0.1	....	....
Snails	13.2	0.1	....	....

* The following species occurred in only trace amounts: rye (*Secale cereale*), sorghum (*Sorghum vulgare*), common yellow oxalis (*Oxalis stricta*), bulrush (*Scirpus* sp.), euphorbia (*Euphorbia* spp.), chickweed (*Stellaria media*), plantain (*Plantago* sp.), mulberry (*Morus* sp.), Pennsylvania smartweed (*Polygonum pennsylvanicum*), dotted smartweed (*Polygonum punctatum*), knotweed (*Polygonum* spp.), common pokeweed (*Phytolacca americana*), prostrate amaranth (*Amaranthus blitoides*), lambsquarters goosefoot (*Chenopodium album*), barnyardgrass (*Echinochloa crusgalli*), mat sandbur (*Cenchrus pauciflorus*), fall panicum (*Panicum dichotimiflorum*), common witchgrass (*Panicum capillare*), dock (*Rumex* sp.), black locust (*Robinia pseudoacacia*), forget-me-not (*Myosotis* sp.), copperleaf (*Acalypha* sp.), fat-hen saltbush (*Atriplex patula*), violet (*Viola* sp.), mustard (*Brassica* sp.), prostrate knotweed (*Polygonum aviculare*), poppy (*Papaver* sp.), Canada thistle (*Cirsium arvense*), crabgrass (*Digitaria* sp.), bird rape (*Brassica campestris*), centaurea (*Centaurea* sp.), amaranth (*Amaranthus* sp.), slim amaranth (*Amaranthus hybridus*), grape (*Vitis* sp.), vetch (*Vicia* sp.), magnolia waterlily (*Nymphaea tuberosa*). Traces of insects and molluscs were also found.

§ See Table 1 for seasonal distribution of specimens.

† Nomenclature after Kelsey and Dayton (1942).

‡ Calculated for only those foods that amounted to 1 per cent or more in the aggregate by volume.

waste places which drops seeds from July to October. It is a staple dove food.

Common oats (*Avena sativa*) was the only other cultivated grain among the major food items. It ranked only slightly behind corn in acreage grown in the county, and it is harvested only a couple of weeks later than wheat. However, it germinates so fast that it does not remain available as a dove food for very long.

Barley (*Hordeum vulgare*) was grown on 3.52 per cent of the small grain acreage in the county, yet it occurred in only trace amounts in the dove crops examined. It is harvested early and is slow to germinate. Although it was ranked as a "fair" dove food by Davison and Sullivan (1963), barley is apparently less important in New York.

Although sheep sorrel (*Rumex acetosella*) was listed by Davison and Sullivan (1963), as "unbeaten" or only tasted, it occurred in 7.2 per cent

Table 5. Grain Crops in Tompkins County in 1963*

Crop	Approximate harvest date	Amount grown	
		Acres	Per cent
Corn (grain)	October 1	7,000	24.6
Corn (silage)	September 7	4,000	14.1
Wheat	July 25	5,000	17.6
Oats	August 7	10,000	35.2
Barley	July 7	1,000	3.5
Buckwheat	September 1	882	3.1
Hay	.....	540	1.9
Total		28,442	100.0

*From: New York State Soil and Water Conservation Needs Inventory (The New York Conservation Needs Committee, 1962) and Ernest J. Cole, Tompkins County agricultural agent.

of the crops examined in this study and represented 0.2 per cent by volume. The fact that panicum (*Panicum spp.*), chickweed (*Stellaria media*), barnyard grass (*Echinochloa crusgalli*), pokeweed (*Phytolacca americana*), and sorghum (*Sorghum vulgare*), all listed as "choice" by Davison and Sullivan, occurred in only trace amounts was probably due to low availability.

Snails made up only 0.1 per cent of the food consumed, but they occurred in 13.2 per cent of the crops. McClure (1943) and Rosene (1939) indicated that snails may be significant in the diet of nesting doves. McClure suggested that both the calcium and salt contents of snails are important to nestlings as a food supplement and to adult females for egg production. In the present study, of 24 doves that had snails in their crops, nine were juveniles, nine were adult males and only six were adult females. Laub (1956), in a study of 51 nesting adult doves in Ohio, found free crop milk after 9 days of incubation and up to 9 days after brooding. He stated that crop-wall development and the stage of nesting are correlated. In the present study, only three of the adult females with snails in their crops also had well developed crop glands.

An attempt was made to determine whether the seeds selected by nesting doves were different from those selected by non-nesting doves. It has been found (Edminster, 1954; Townsend, 1906) that nestlings less than 3 days old are fed small seeds, but it is not known whether

nesting doves select specific seeds as a supplement for egg or "pigeon milk" production. Using the first 10 species in Table 4, their relative selection by doves with and by doves without well developed crop glands was tested by chi-square. Crop gland development was considered an indication of nesting. The test showed no significant difference at the .05 level of probability. The calculated value was 18.1 and the tabulated value was 28.9. Nevertheless, the large calculated value indicates that there was some difference. Of the 36 adults tested which had well developed crop glands, several may have been selecting small seeds for nestlings which were less than 3 days old.

Table 6 shows the more important food items found in six other food habits studies of mourning doves in the East and Midwest. Corn ranked first or second in all six. Wheat and foxtail (bristlegrass) were

TABLE 6. RELATIVE IMPORTANCE OF MOURNING DOVE FOODS ACCORDING TO OTHER STUDIES IN THE EAST AND MIDWEST

Authority and locality	Food and rank				
	1	2	3	4	5
Chamberlain (1960)..... Virginia	Eyebane	Corn	Ragweed	Grain sorghum	Crabgrass
Cummings and Quay (1953). North Carolina	Crabgrass	Corn	Foxtail	Paspalum	Wheat
Hanson and Kossack (1963). Illinois	Wheat	Corn	Yellow foxtail	Giant foxtail	Green foxtai
Korschgen (1958)..... Missouri	Corn	Wheat	Yellow foxtail	Giant foxtail	Small wild bean
Martin *et al.* (1951)..... Northeast.....	Foxtail Corn Wheat	Buckwheat Ragweed Pokeweed	Knotweed Crabgrass	.....	.....
Sprunt (1957)..... Virginia	Corn	Copperleaf	Ragweed	Foxtail Smartweed	Smartweed Wheat

among the top five food items in five of the studies, ragweed in three and buckwheat in only one. Except for buckwheat, these findings compare well with those of the present study.

Further indication of the importance of individual food species can be derived by measuring their use in relation to their availability. One approach, for the grains, would be to compare the acreage grown with the degree of use by doves. Another method is to plot the proportionate volumes of the various seeds as found in the dove crops each half-month. Then, if one knows when these seeds become most readily available (i.e., by harvest or natural seed drop), the degree of correlation can be determined.

Graphs of this type of data for the five top-ranking food species are shown in Figures 3 and 4. Corn, which is not harvested until Octo-

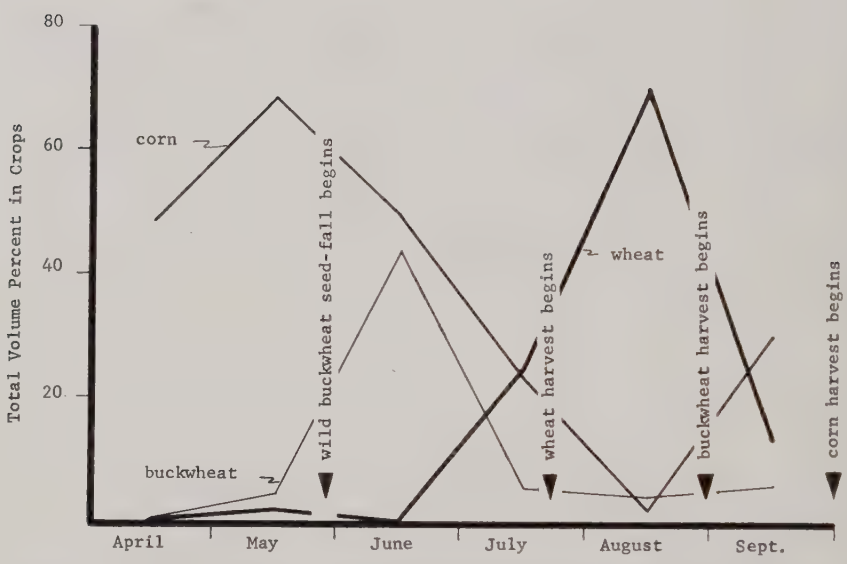

Figure 3. Seasonal selection of corn, wheat and buckwheat by mourning doves examined.

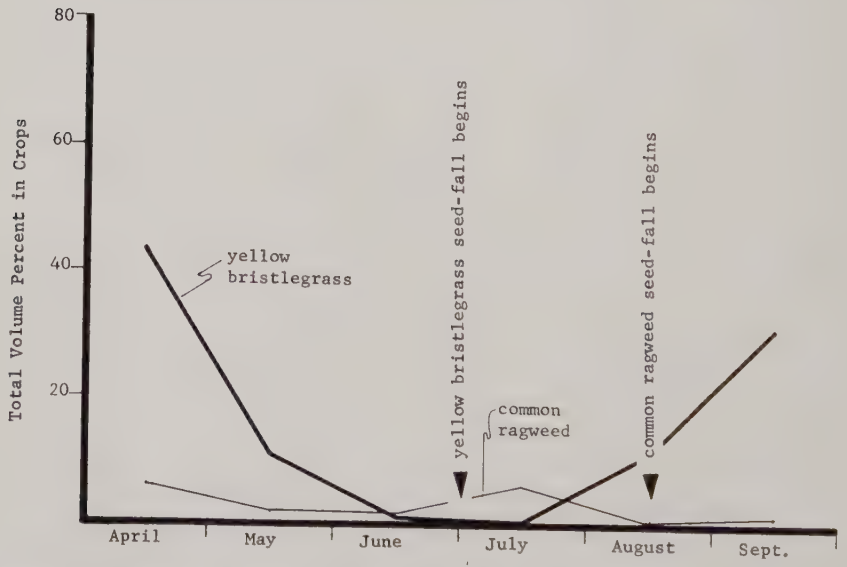

Figure 4. Seasonal selection of yellow bristlegrass and common ragweed by mourning doves examined.

ber, showed intensive use by doves the following spring. Buckwheat grows both in the wild and under cultivation. Wild buckwheat casts seeds from June to September; when cultivated it is not harvested until

September. The greatest use of buckwheat by the doves examined occurred in June after the wild plants dropped their seeds. The slightly increased use in September suggests a response to availability of cultivated buckwheat; however, the difference may simply reflect sampling error. Wheat is first harvested in July. At that time use of both buckwheat and corn fell off sharply, and that of wheat increased by over 80 per cent. After wheat became less available in late August, there was greater use of buckwheat and yellow bristlegrass (Figure 4). Yellow bristlegrass was a major item in the diet during the periods before and after the time when wheat and buckwheat were readily available.

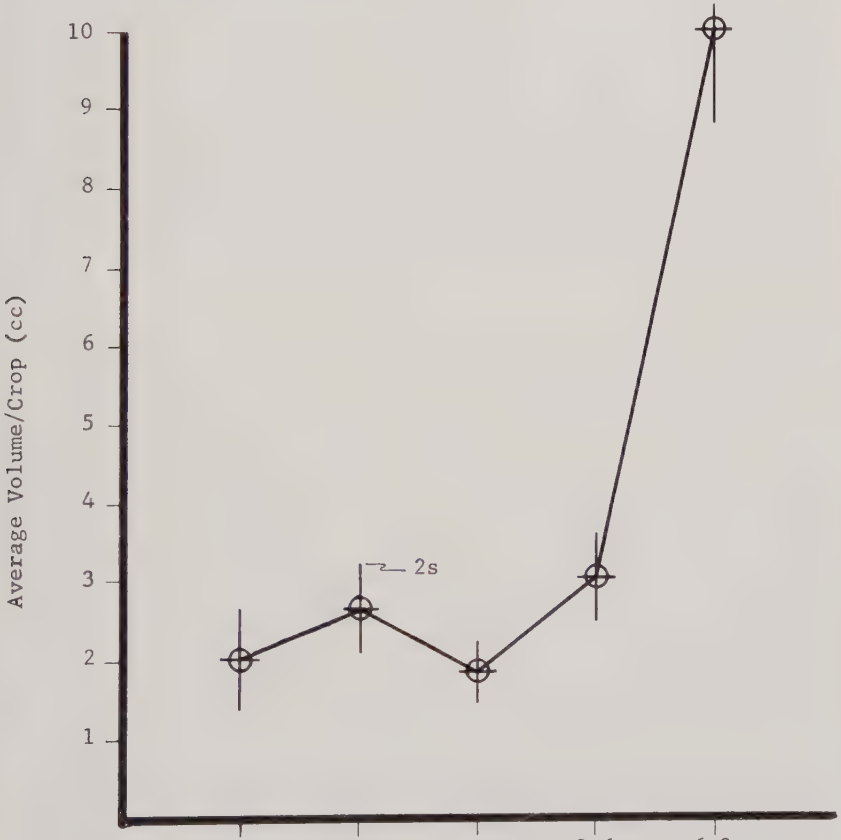

Figure 5. Volume of food in crop in relation to the time of day for 175 mourning doves examined.

This, as well as its use at other times, indicates that yellow bristlegrass is a staple food. Except during midsummer, it was eaten to a greater degree than ragweed. Common ragweed showed fairly constant use from March through September which indicates that it is available almost the year around and serves as a staple but not highly selected, food. The findings from this approach reflect almost exactly the ranking of these species in Table 4. Figure 3 indicates that buckwheat is selected over corn, but since it is available for a shorter period of time, it makes up less of the total volume. Duncan's new multiple range test indicates that the rank of these two species could be interchanged.

An attempt was made to determine the time of day when the feeding effort was most concentrated. The average volume of food per crop was plotted against time units of 3 hours each throughout the day (Figure 5). There was little difference in the food volume from 6 a.m. to 6 p.m., but a highly significant increase occurred during the period from 6 p.m. to 9 p.m. The implication is that doves enter the roost in the evening with a full crop and feed only leisurely during most of the day. The author also examined doves which were shot entering a roost in southeastern Pennsylvania; almost all had full crops. Personal communications with hunters in other states also support this view.

Breeding

Data for three physiological characteristics of the mourning dove were considered in relation to the pattern of the breeding season.

Relation to Crop Gland Development Assuming that adults whose crop glands were developed were nesting, the frequency of such specimens among the birds collected during the spring and summer of 1963 was plotted (Figure 6). This indirect approach to nesting phenology was also used by Taylor (1941). The graph suggests two primary nesting peaks (early May and August-September) and two lesser peaks (late June and late July). It is doubtful that the nesting peak for August-September was as large as indicated because only six adults were collected during this period. Also shown for comparison are data reported by Schemnitz (1964) who plotted the number of active nests found from April through September in Centre County, Pennsylvania, for each of the two previous years. The two sets of data are quite complimentary. It is believed that individual females rarely nest during every nesting period. There is probably a high degree of synchrony in breeding during the first nesting period but less thereafter. Perhaps each nests during only one or two of the last three nesting periods.

This breeding pattern differs from the findings of several other investigators. Most other studies have indicated but one nesting peak. Hanson and Kossack (1963), in Illinois, reported a large nesting peak in

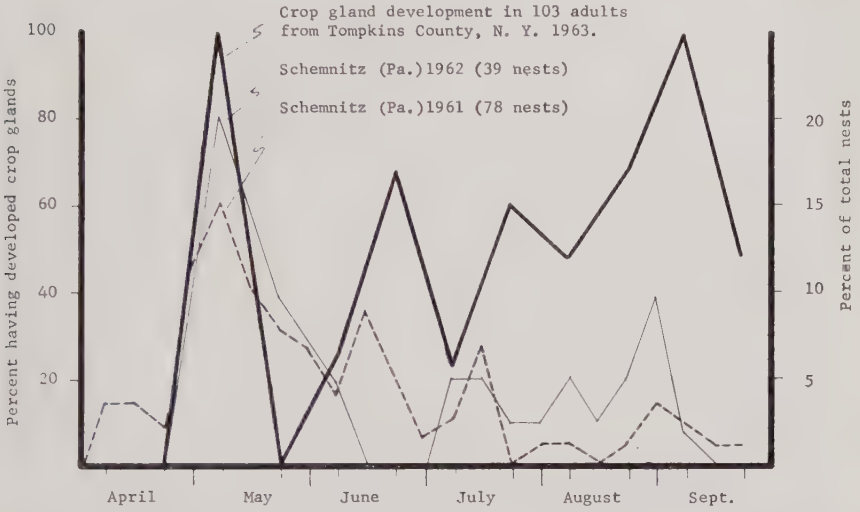

Figure 6. Comparison of productivity peaks of mourning doves as indicated by crop gland development in specimens from New York and by frequency of nesting reported by Schemnitz (1964) for Pennsylvania.

Figure 7. Seasonal trend in size of testes of mourning doves examined.

early May and a small peak in late June which correspond to the two early peaks observed in this study. Sprunt (1957) found a single peak

in early May in Virginia. Pearson and Moore (1939) found the peak nesting period to be May-June in Alabama. Bolt and Hendrickson (1952) found a single peak in mid-August in North Dakota.

Relation to Testis Size Length measurements of adult male testes were taken and averaged for each half-month (Figure 7). Sample sizes were very small, but the data are presented as an indication of the probable size changes and breeding condition. Testis size increased rapidly immediately preceding the first nesting peak. It then maintained a generally high level until late August when a precipitous decline marked the termination of the breeding season. The small testis size in early August corresponded to the low in nesting frequency found at the same time; however, two standard deviations from each of the points in August overlap, indicating that this low was not statistically significant. The large testis size in late June and early July agrees with the findings of Pearson and Rosene (1938) for the southern states based on testis weight. Jenkins (1955), in Georgia found that males attained full breeding condition in February and did not show testis regression

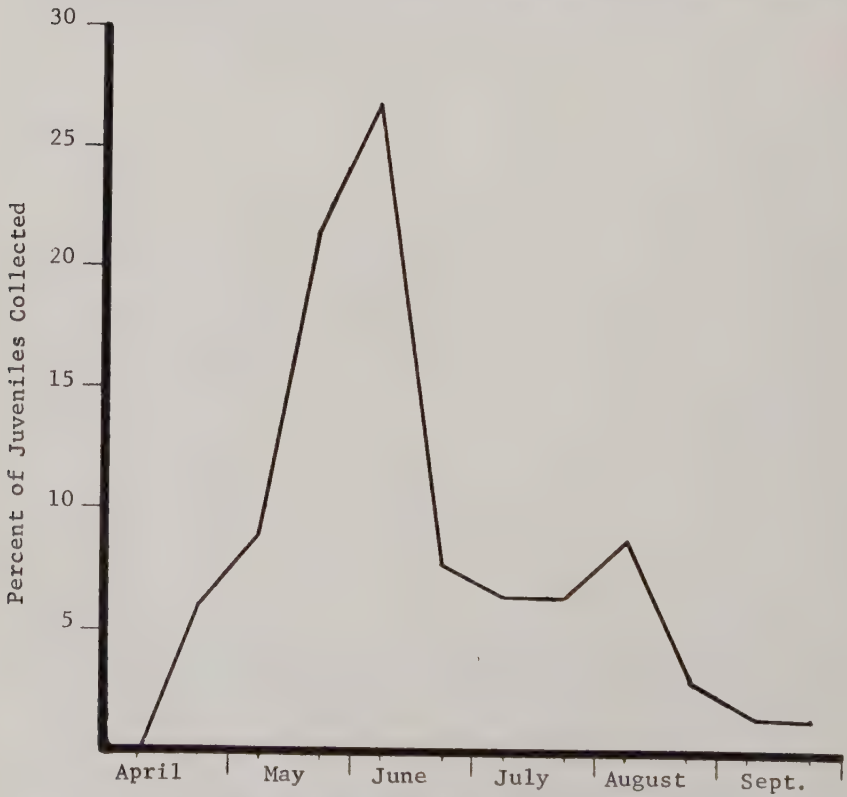

Figure 8. Hatching curve calculated from data on wing molt for 77 juvenile mourning doves examined.

until mid-September. This difference may be attributed, in part, to the latitude difference between Georgia and New York.

Relation to Wing Molt The hatching dates for juvenile specimens were back calculated from the date of collection on the basis of wing molt (Figure 8). The two peaks derived in this way do not correspond to those in Figure 6, but occur during indicated lows. The author feels that the pattern derived from crop gland data is more reliable, especially since it is strongly supported by Schemnitz's study.

Movement of Juveniles

Jenkins (1955) found that 80 per cent of the doves taken in the South during September were juveniles, and that most of these juveniles were hatched in May and June. Only 40 per cent of the doves collected in Tompkins County in September were juveniles, and less than half of these were hatched before July. C. C. Anderson banded 14,406 mourning doves from March 1950 through February 1958 at West Palm Beach, Florida (Schultz and Winston 1960). The proportion of juveniles in the unbanded population increased from a low in March to over 90 per cent in May, and it remained above that level through November. Schultz and Winston suggested that this high percentage of juveniles in the late fall population was not necessarily due to nesting success, but may have reflected a high incidence of migrant juveniles. The fiindings of the present study tend to agree with those of Hanson and Kossack (1963) who say, ". . . doves hatched late in the nesting season tend to make up a larger share of the hunters' bags in northern Illinois than do those hatched early in the season". Early-hatched juveniles in the northern states probably move south before the end of the breeding season.

The Mourning Dove as a Possible Game Bird in New York State

Doves are hunted in 31 states and are considered to afford excellent sport. It is often suggested that dove hunting might be feasible in New York. Three major questions are involved: (1) does New York support a large enough harvestable crop of doves to justify an open season; if so, how will hunting affect future populations; (2) even without hunting can the State's dove population be expected to maintain itself if available habitat continues to decrease; (3) to what degree would harvestable levels depend on the influx of fall migrants. Some information on these questions was acquired during this study.

Annual mortality is 60 to 85 per cent among juvenile mourning doves, and 55 to 58 per cent among adults (Austin, 1951; Hickey, 1952; Kiel, 1959b; Quay, 1951). Based on band recoveries, hunting accounts for only about 3 to 4 per cent of the total mortality (Quay, 1951; Shaw,

1956). From these figures it would appear that hunting pressure has little effect on dove populations.

The U.S. Fish and Wildlife Service's "breeding population index" for the eastern management unit in 1963, the third year of decline according to Wight and Baysinger (1963), showed a 3.6 per cent decline from the 1962 level. Hunting states showed a 7.2 per cent decline, but non-hunting states showed an 8.0 per cent rise. In New York the 1963 index was equal to the mean for the past seven years. Hunting pressure is not the only variable involved, but its effect (direct or indirect) may be greater than formerly suggested.

Despite a slight drop in the eastern breeding population, the mourning dove seems to be increasing its range northward. Nevertheless, abandonment of small farms and other land use changes are slowly decreasing the available dove habitat in New York. Russell (1954) speaking in particular of the mourning dove said, "The problem of management lies not in matters of increasing the population but in wisely utilizing the new crop produced each year". In New York, however, more suitable habitat would be required to provide a harvestable crop of locally raised juveniles since banding studies show that this age group comprises 65 to 70 per cent of the annual kill when hunting is done.

The opening date for dove hunting has usually been set by the U.S. Fish and Wildlife Service at September 1. A large proportion of the doves from New York have begun migration by this time, and most of those still in the State are still nesting. The literature is replete with recommendations that the season not begin before October because of this late nesting. Weber (1959) stated that "When the young have lost even one parent, most students of the subject agree that they either starve, or, if of sufficient size to forage for themselves, feed before their natural resistance (to trichomoniasis) has developed". Weber (1963) stated that nationwide surveys reveal that 33 per cent of the dove population is still nesting in September. Laub (1956) studied the effect of disruption on 65 nests. He found that nests were not successful if one adult was removed during incubation; also, one adult was unable to produce sufficient crop milk for two nestlings. But in New York it would not be simply a matter of waiting for nesting to end before opening the season, because almost all late nesting doves would migrate as soon as they had fledged their young. Overwintering is increasing in the State, but flocks are still small.

Kiel (1959b) found that, in the eastern management unit, 65 per cent of banded doves shot had been banded in the same state. However, the data were heavily weighted by records from the South and Southeast where the effects of migration are probably not felt until later in the fall. Migration begins earlier farther north and harvest-

able doves migrate through New York at the time an open season might be held. However, populations are not great enough to the north to provide any sizeable influx of migrants except, possibly, on Long Island and in the lower Hudson Valley.

In 1944 McClure gave six reasons why there should be no dove hunting north of the 37th parallel: (1) late nesting because "if the season opens in September, one-fifth of the population is endangered"; (2) an early annual migration and the fact that those that are nesting in September migrate immediately after their young are fledged; (3) the scarcity of overwintering doves; (4) the close association of doves with man and the fact that hunting would jeopardize his safety and property; (5) the dove's songbird status; and (6) its beneficial food habits.

The last three reasons are of slight consequence today. Experience in other states has shown that while doves sometimes concentrate near urban areas, they can be hunted safely and successfully in rural areas. The species has also been able to maintain the status of both a game bird and a songbird in over half the states. And it has been shown that, although its food habits are not injurious, neither are they largely beneficial. Doves do eat vast amounts of weed seeds, but this is only a trifle compared with the enormous number of seeds cast by weeds each year. McClure's first three reasons, however, still appear to be applicable in New York.

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A STOCKING FORMULA FOR HEAVILY FISHED TROUT STREAMS[1]

William H. Kelly Conservation Biologist
New York State Conservation Department

ABSTRACT

A formula was developed to calculate the results of various rates of stocking large-sized trout in terms of return to the angler using creel census data concerning the catch and fishing pressure. The formula was field tested with marked (fin-clipped) brown trout on Willowemoc Creek with promising results. It was also applied to data from Esopus Creek, Peekskill Hollow Creek and the East Branch of the Delaware River to illustrate how management recommendations based on it might vary. An important feature is that it relates directly to the performance of hatchery trout during the first season after stocking. It also permits assessing the contributions of the wild population and of carryover fish from previous stocking. The value of a mathematical approach is considered to lie not so much in producing precise figures as in providing measurements of the dynamics of the existing fishery that may be used to guide management policy.

For a long period of years stocking hatchery-reared trout has continued to play a major role in the management of angling. It has been generally recognized that there are many problems to be considered including recommended numbers of fish to be stocked, checking of results and evaluation of stocking against other management methods. Over the years hatcheries have accelerated production of large-sized trout (mostly yearlings) which are so expensive as to limit the numbers available in relation to total areas requiring stocking. Stocking recommendations for small-sized trout (mostly fingerlings) have generally been based on a concept of carrying capacity as estimated from field survey data on the amount and quality of available habitat. Since time for growth is involved, the estimate of carrying capacity has been projected on survival estimates covering the time required for such fish to attain catchable size. Large-sized trout, subject to immediate or short-term capture, cannot usually be stocked and maintained at the full carrying capacity of a water without prohibitive expense. A major problem to solve for improving use of these fish is to measure the short-term results of stocking and to adjust numbers to an effective and economical level. Such an evaluation can also serve to compare such stocking against alternative methods of management.

DEVELOPMENT OF FORMULA

A study was undertaken to evaluate the results of stocking in terms of return to the angler using a stocking formula that could be applied to a given water based on statistics concerning the catch by anglers and

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[1] A contribution of Federal Aid in Fish and Wildlife Restoration Project F-9-R based at the Fish Laboratory, Livingston Manor, N.Y.

the fishing pressure. The basic equation $Q=\frac{C}{P}$ for catch per unit of effort (Q) in terms of total catch (C) and fishing pressure (P) was modified to

$$Q=\frac{SR}{P}+\frac{W}{P}+\frac{X}{P} \quad \text{(Equation 1)}$$

where: Q=catch per unit of effort
S=number of trout stocked (type of primary interest)
R=return (as percent) of trout stocked
W=catch of wild trout
X=catch of trout in any other category
P=angling effort (as hours or trips)

Separating the catch data in terms of stocked trout, wild trout and "other" trout permits determining the relative contributions of different components of the population. If one is interested in the contribution of a particular type of hatchery fish (species, size, etc.), data for it can be used as SR and data for other hatchery fish stocked during the same year will be represented by X.

Analysis is also facilitated by presenting the catch for the type of trout of primary interest in terms of two variables (SR). There has been a tendency to stock as if only one variable existed, i.e., the number of fish. The one-variable approach leads to the inference that better fishing follows heavier stocking and assumes that no great decrease in the rate of return occurs when more fish are stocked. Often, this is not the case, and the actual relationship becomes evident when both factors are used. Another advantage relates to the possibility that the rate of return by angling can be increased so that greater catch per unit of effort could result from the same level of stocking. Perhaps stocking might even be reduced without loss of angling success.

The equation may then be used as a stocking formula by arbitrarily selecting a desired value for catch per unit of effort and using a creel census data representative of the water involved. In this form the equation becomes

$$S=\frac{PQ-(W+X)}{R} \quad \text{(Equation 2)}$$

The inverse relation between number stocked and rate of return is well illustrated when the data are put in this form, e.g., to obtain any predetermined catch per unit of effort (Q), the number to stock decreases as the percentage of return increases, assuming that the catch from other sources (W and X) and the pressure (P) are constant.

In recent years catchable-sized trout have been used increasingly to stock streams where fishing pressure is heavy. There is considerable evi-

dence indicating that the benefit from such stocking lies largely in providing "instant" fishing and that survival to subsequent years is generally low. In such situations, stocking according to fishing pressure, rather than carrying capacity alone, may be more realistic management. An important feature of the formula developed here is that it relates directly to the performance of hatchery trout during the first season after stocking.

The formula was field tested on Willowemoc Creek, one of the major trout streams in the Catskill region. To illustrate how recommendations based on it might vary, the formula was also applied to data available from three other streams in southeastern New York in which the trout stocked had been marked and creel censuses conducted: Esopus Creek, Peekskill Hollow Creek and the East Branch of the Delaware River. All are good quality trout waters and are moderately to heavily fished.

WILLOWEMOC CREEK

Willowemoc Creek is a major tributary of the Beaverkill River. It is a stream of medium size about 17 miles in length and flows largely through woodland. The gradient is moderate, and gravel-bottomed pools alternate with short riffles.

Test of the Formula

In 1963 this stream was stocked with 14,100 yearling and 1,000 2-year-old brown trout from a State fish hatchery having water of similar quality. The yearlings ranged in length from 6.7 to 10.4 inches and averaged 8.35 inches. All the fish were fin clipped for positive identification and were held for several days prior to stocking to assure that they suffered no postclipping mortality. Stocking was done in two increments, one in April and one in May. In addition to these fish, wild brook trout, wild brown trout and hatchery brown trout from stocking in previous years were also present.

Throughout the open season (April 1-September 30) in 1963 fishermen were interviewed, and the number of hours fished and the number of trout caught were recorded. The catch was recorded separately for the different groups involved. Although fish stocked in previous years had been fin clipped, it was not always possible to differentiate them from wild fish because of fin regeneration, natural deformity of the fins of wild fish or failure to observe clipped fins. The data for the season as a whole are given in Table 1.

These figures were then substituted in Equation 1, using SR to represent the catch of yearling hatchery trout stocked in 1963. For convenience, W represented the total catch of all wild trout and hatchery trout stocked before 1963. Also, X was converted to S_1R_1 to use the data

TABLE 1. NUMBER OF TROUT STOCKED AND CREEK CENSUS DATA FOR WILLOWEMOC CREEK IN 1963 AND 1964

Type of trout	Number stocked	Number caught	Return (per cent)	Angling * effort (hours)
1963				
Hatchery brown trout stocked in 1963				
Yearling	14,100	7,811	55.4	16,556
2-year-old	1,000	950	95.0	16,556
Hatchery brown trout stocked earlier plus wild brown trout and brook trout	..	3,759	..	16,556
1964				
Hatchery brown trout stocked in 1964				
Yearling	28,200	13,536	48.0	15,659
2-year-old	1,000	820	82.0	15,659
Hatchery brown trout stocked earlier plus wild brown trout and brook trout	..	2,066	..	15,659

* Based on hours fished during successful angler trips, i.e., those on which the angler retained one or more trout.

for 2-year-old hatchery trout stocked in 1963. Solving the equation gave the catch per unit of effort for all types of trout. This was 0.756 trout per hour.

In 1964, it was decided to double the stocking rate of brown trout yearlings, but to stock the same number of 2-year-old fish and to assume that the other factors would be constant. Accordingly, 28,200 yearlings and 1,000 2-year-olds were stocked. To minimize variables, the fish were comparable in size to those used the year before and they were stocked, part in April and part in May[2], at the identical locations. A creel census was again carried on and the data (Table 1) were analyzed in the same way as before. Catch per unit of effort was found to have been 1.048 trout per hour or 14.6 per cent less than the predicted value of 1.228 derived from Equation 1.

Prediction of fishing quality within an error of 15 per cent is considered close in view of the variables that could effect the outcome such as changes in fishing pressure, in the percentage return of stocked fish, and in the number of wild trout taken. The fact that actual catch per

[2] It is felt that it would be better to stock under comparable stream conditions from year to year than on the same date.

unit of effort was below that predicted is important as will be discussed later.

In 1964 the return of trout stocked in April was lower than in 1963. It is felt that this was due mainly to downstream migration associated with flood conditions that occurred rather than to natural mortality. Willowemoc Creek flows into the Beaverkill River which, about 16 miles downstream, joins the East Branch of the Delaware River. Creel census records indicated that about 6 per cent (850 fish) of the trout stocked in Willowemoc Creek in April were taken in the Beaverkill River. There also are reliable records of such fish being taken in the East Branch of the Delaware River.

Other Relationships Observed

Doubling the stocking in 1964 appeared to have no important effect on the total angling effort. The total angler trips increased about 5 per cent, but the average length of a trip decreased from 3.49 to 3.30 hours. Total angling hours were 33,712 in 1963 and 33,362 in 1964. It may be noted, however, that widespread publicity of the greater stocking was avoided.

The number of successful fishing trips (one or more trout taken per trip) remained even more constant, being 4,744 in 1963 and 4,745 in 1964, but the hourly catch rate (for trout actually creeled) increased about 39 per cent implying that most of the additional fish taken were caught by anglers who were catching fish in the first place. This agrees with the findings of McFadden (1961) and Cooper (1952) that an increase in the numbers of trout available is of advantage primarily to the more capable anglers and, at best, of slight advantage to the less adept anglers. Therefore, stocking more trout may not, in itself, be effective in increasing the average catch of all anglers who fish the water.

If this thesis is generally correct, then successful effort is better than total effort as a measure of fishing pressure. In this connection, Rupp (1961) and McFadden (1961) stated that data based on total effort may reflect differences in average angler ability rather than actual differences in the fishery itself. Commenting on difficulties encountered in comparing fishing quality between urban-accessible and remote waters, Rupp added that "Novices may predominate on waters near cities and towns, but be less numerous on remote waters. It is therefore possible to get different catch-per-unit-of-effort values from two waters of equal fishing quality if one is remote and the other is near a center of population."

During the creel census on Willowemoc Creek it was found that many of the more proficient anglers were releasing most (and sometimes all) of the trout they caught. Most of such data were considered statistically unsound because of angler bias. However, there were a few

reliable accounts of catch rates in the 10 to 25 trout per hour range, the incidence being greater in 1964 when stocking was doubled. As would be expected, these high catch rates generally occurred during the period immediately following stocking. Where large numbers of trout are caught and released, the representativeness of catch-per-unit-of-effort figures for fish actually creeled is lowered. Nevertheless, although its effect is difficult, if not impossible, to measure, this type of fishing must be considered in assessing the total aesthetic value of the fishery.

ESOPUS CREEK

Esopus Creek, another popular trout stream of the Catskill region, flows into Ashokan Reservoir. It is generally similar to Willowemoc Creek, but it is subject to marked changes in volume in its lower half where the discharge from Gilboa Reservoir empties into it. It has a high biological suitability for trout.

In 1962 this stream had been stocked with 56,591 yearling hatchery brown trout, and a creel census had been conducted. The data (Table 2) were substituted in Equation 1 using successful trips as *P*. For all trout, the catch per unit of effort was 4.661 trout per trip. However, in spite of very heavy fishing pressure, wild trout and hatchery trout surviving from stocking in previous years yielded a catch of 2.250 trout per trip compared with 2.411 for the hatchery fish stocked during the same season. Hatchery brown trout that had been stocked in previous years represented only a small fraction of the wild and carryover group.

These data indicate that, except during the year in which it was done, stocking had little effect on fishing success and that fishing success depended as much on wild fish as on hatchery fish. Under such circumstances, there might be justification for more emphasis on the wild population and less on stocking in the management program. Measures to increase the wild population might include a decrease in the catch limit and an increase in the size limit.

TABLE 2. NUMBER OF TROUT STOCKED AND CREEL CENSUS DATA FOR ESOPUS CREEK IN 1962

Type of trout	Number stocked	Number caught	Return (per cent)	Successful trips *
Hatchery brown trout yearlings stocked in 1962	56,591	15,732	27.8	6,525
Hatchery brown trout stocked earlier	..	1,602	..	6,525
Wild rainbow trout	xxx	12,286	..	6,525
Wild brook trout	xxx	791	..	6,525

* Of 14,863 total trips.

With respect to stocking, if 3.0 trout per successful trip were arbitrarily considered satisfactory, the number of hatchery yearlings to stock may be determined from Equation 2. Hence, letting 3.0 equal Q and assuming that the other factors would be constant, solving for S would give 17,612, a cutback in stocking of 38,979 trout. Further reduction in stocking could occur if measures to raise the percentage return were effective. Also, improvement in the quality of the fishery could occur if management to increase the production of wild trout were successful. The savings that would accrue from reduced stocking might be used for management to improve the natural production of the stream.

OTHER EXAMPLES

By deciding on a catch per unit of effort which he feels represents a reasonable rate of angling success for a particular fishery, a manager can then use creel census catch and pressure data to determine the required number of trout to stock. In the following examples 3.0 trout per successful trip was used as the desired value. In both cases, the existing catch per unit of effort was less than that, and therefore the stocking of more trout was indicated.

Peekskill Hollow Creek

This is a small stream that flows into the Hudson River at Peekskill and is about half an hour's drive from New York City. In 1960 it had been stocked with 4,700 yearling hatchery brown trout. The creel census data obtained at that time are given in Table 3. Substituting

Table 3. Number of Trout Stocked and Creel Census Data for Peekskill Hollow Creek in 1960

Type of trout	Number stocked	Number caught	Return (per cent)	Successful trips
Hatchery brown trout yearlings stocked in 1960	4,700	2,120	45.1	1,389
Hatchery brown trout stocked earlier	xxx	681	..	1,389

these data in Equation 1 gave 2.016 trout per successful trip as the existing rate of success. Raising this value to 3.0 and otherwise using the same data in Equation 2 gave 7,729 as the number of trout to stock, an increase of 3,029. Such an increase, i.e., about 64 per cent, might well be justified in a heavily fished stream of this sort.

East Branch of the Delaware River

This is one of the larger trout-inhabited rivers in the State and has

a high biological potential. Below Pepacton Reservoir it is physically atypical of most good fishing rivers, being a tailwater stream subject to wide extremes in flow and temperature due to the release pattern from the Reservoir. It has a low gradient and courses a wide, flat valley. An abundance of long, wide pools connected by moderately flowing runs makes this potentially a big fish producer in years when temperatures result in a long growing season.

Survival of stocked trout has been variable, but returns have generally been quite low. Creel census data for 1960 (Table 4) are fairly

TABLE 4. NUMBER OF TROUT STOCKED AND CREEL CENSUS DATA FOR THE EAST BRANCH OF THE DELAWARE RIVER IN 1960

Type of trout	Number stocked	Number caught	Return (per cent)	Successful trips
Hatchery brown trout yearlings stocked in 1960	23,912	813	3.4	1,563
Hatchery brown trout stocked earlier	xxx	2,280	..	1,563

typical. Stocking in that year amounted to 23,912 yearling hatchery brown trout, and Equation 1 showed fishing success to have been 1.976 trout per trip. Raising this value to 3.0 and otherwise using the same data in Equation 2 gave 80,300 as the number to stock to achieve the higher rate of success. This would mean stocking 56,388 additional fish, an increase of about 236 per cent. It is felt that such an increase would be neither biologically nor economically justified. Rather, improvement of fishing in this stream must depend on other measures.

The East Branch affords a good example of the potential importance of employing management practices that might increase angler satisfaction by means other than merely increasing the numbers of trout stocked. This approach deals primarily with getting a greater return during the same season the fish were planted. However, management might also increase survival to subsequent years. Thus, another approach might be to maintain stocking and manage for carryover or "quality" fish. Growth rates are extremely good in this river, and carryover fish tend to be exceptionally large. It is not uncommon for trout that survive for 14 months after being stocked to grow from 7 inches to 12 inches or more in length in that time.

APPLICATION TO LAKES AND MARGINAL TROUT STREAMS

Since this formula deals primarily with exploitation rates, it should be useful in measurement and control of most trout fisheries, including

those in marginal streams and lakes. A marginal stream is one having a low carrying capacity for trout, or perhaps no suitable carrying capacity on a year around basis. Such streams will support trout chiefly for the first few months of the season. Nevertheless, there is considerable need for stocking streams of this sort near population centers, especially where good quality streams are wanting. No data were available for evaluating the formula in situations of this type. It is probable that, where fishing pressure is very high, the degree of stocking required to provide "good" fishing would be economically impractical. But the equation would give the manager a measure of the effect on the stocking done.

Neither were data available for lakes in New York. However, C. L. Sowards (personal communication, 1965) confirmed success in using a similar approach to manage certain small, rather marginal lakes in the Black Hills of South Dakota by controlling the numbers of trout stocked in accordance with expected fishing pressure. Based on data collected, a catch rate of 0.5 trout per hour and a return of 75 per cent of the catchable-sized hatchery trout stocked were decided upon as criteria of fishing success. Since the contribution of wild and carryover trout to the catch was found to be 0.04 trout per hour, it was necessary to provide 0.46 trout per hour by stocking. For a 75 per cent return this meant stocking at a rate of 0.62 trout per hour of estimated fishing pressure. Spot creel censuses were made to check results on four lakes managed in this way, and the program was considered to be working quite well. Mean angling success for these lakes was 0.46, 0.55, 0.66 and 0.77 trout per hour.

DISCUSSION

The formula developed here assumes that, for a trout water of given biological potential, the take by angling is the most important factor limiting the quality of fishing it affords. To compensate for the exploitation by man, stocking of hatchery trout has been carried on for many years. But stocking rates have been based primarily on the carrying capacity for the stream. Through creel census data this formula takes into consideration also the fishing pressure and rate of return to the angler of the stocked fish as well as other components of the population. It may, therefore, be used to determine the degree of stocking that would be required to produce a satisfactory return to the angler. On the other hand, it may also be used to determine how much the rate of return of hatchery fish would need to be raised to achieve the same result without increasing the number stocked. Although it is believed to be applicable to a wide variety of waters, it is probably most useful for streams that have a high biological potential for trout and that are both heavily stocked and heavily fished.

Using the formula, a manager could decide not only what might be done, but what might not be done, within the contexts of biology, economics and aesthetics. For example, higher return of stocked trout is generally desirable, and it would be possible to determine how measures to increase such return might affect stocking rates and catch per unit of effort. Also, it would be evident when it would be economically impractical to provide the number of hatchery fish required to produce a certain quality of fishing. Knowledge of the contribution of wild and carryover trout would indicate when it might be desirable to emphasize production of the wild population.

The value of a mathematical approach lies not so much in producing precise figures as in providing measurements of the dynamics of the existing fishery and also to help in answering some basic questions. How many people fish there? Of what value is stocking? What is the wild trout production? Is the present fishery satisfactory? If satisfactory, what can be done to maintain it? If unsatisfactory, what can be done to improve it? In improving an unsatisfactory fishery, should management relate more to the wild population or to stocked fish? If stocking is involved, should the goal be an increase in catch during the same season or "quality" fishing through management for carryover fish? In either case, how many fish should be stocked to provide a reasonable expectation of success?

As mentioned previously, increasing the rate of stocking may produce returns per unit of effort that lie below predicted rates. Further tests at various rates together with analysis of stocking costs may delineate a trend toward diminishing returns and make it possible to recommend stocking rates that are effective and within financial limits.

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SOME EFFECTS OF WEATHER AND OTHER INFLUENCES ON SUMMER ROADSIDE COUNTS OF COTTONTAILS[1]

Philip U. Alkon — Conservation Biologist
New York State Conservation Department

ABSTRACT

The effect of certain weather conditions and other environmental factors on early-morning roadside counts of cottontail rabbits was studied in July each year from 1958 to 1963 on four routes consisting largely of secondary roads in Albany County. Rain, heavy fog and winds 8 m.p.h. or higher reduced counts significantly. Other forms of precipitation, as well as temperature and light, had less effect. Little or no relation was found between counts and barometric pressure, relative humidity, cloud cover, wetness of the road surface, or the number of predators or vehicles encountered. On one route surveyed three times each morning, counts were consistently highest on second runs (begun nearly one hour after sunrise).

Annual summer roadside surveys of cottontail rabbits *(Sylvilagus)*[2] may afford a practical basis for predicting gross trends in hunting season population levels. Preliminary study had revealed that counts were generally higher in mid and late July than at other times during the summer and that more rabbits were seen in the early morning than in the evening. It was also found that counts varied considerably from day to day. Because the changes were often similar for different routes run simultaneously, weather conditions were suspected of being at least partially responsible. To standardize a survey method and interprete the resultant data, a study of the nature and extent of weather effects was undertaken. The influence of several non-weather factors was also investigated.

METHODS

Data were collected in July on routes consisting largely of secondary roads in Albany County. Three were surveyed simultaneously on up to 10 consecutive mornings each year from 1958 to 1963. A fourth was covered three times each morning for a similar period each year beginning in 1960. Roadside counts were made from an automobile travelling 15 to 20 m.p.h. All rabbits seen, regardless of their proximity to the road, were counted and, insofar as possible, classified by size as adult or juvenile.

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[2] In the area in which these observations were made, the eastern cottontail (*Sylivilagus floridanus*) was the only species of this genus known to occur.

Other data, such as vehicles and predators encountered, were also recorded. The average starting time for each route ranged between 5:30 a.m. and 5:45 a.m.[3]

The three original routes averaged about 25 miles in length, and roadside surveys had been made on them for several years prior to 1958. During the present study two types of weather information were used. The first was observers' estimates of wind speed, precipitation, road wetness and sky cover; in addition, temperature measurements by thermometer were begun in 1960. These on-route observations were made at both the start and conclusion of each run as well as during the run if noticeable changes took place. The second type of information was U. S. Weather Bureau data recorded at the Albany County Airport located about 9 miles from the center of the area covered by the routes and at about the same elevation. Especially useful were hourly measurements of temperature, barometric pressure, relatively humidity, wind speed and direction, cloud cover, and precipitation.

By 1960 it became apparent that further progress might largely depend on more accurate on-route measurements of weather conditions. For this purpose a roughly circular, 7-mile "weather route" was established, also in Albany County[4], and observations were made on it from 1960 to 1963. A station set up on the route housed instruments for measuring temperature, barometric pressure, relatively humidity, wind speed and light intensity. Much of the data were collected on recording devices[5]. Estimates of precipitation, road wetness, and cloud cover were also made.

The data were analyzed to correlate daily variations in individual weather factors with those in the number of rabbits recorded. Several methods, statistical as well as subjective, were used. Generally, statistical analysis was used when the available data were adequate. Thus, this treatment could be applied to temperature data in nearly all instances, but it could be used to a much lesser degree for factors such as rain, road wetness and cloud cover.

RESULTS

A large amount of data were collected. Those for the rabbits observed are summarized in Table 1. The weather factors studied are discussed separately with respect to their relationship to the number of rabbits seen.

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[3] Throughout this paper time of day refers to Eastern Daylight Saving Time.

[4] Throughout this paper the three previously established routes are designated Routes 1, 2 and 3, respectively; the "weather route", as Route 4.

[5] These included a hygrothermograph, used in 1961, 1962 and 1963; a device for recording light intensity, used in 1962 and 1963; and a barograph used in 1963.

Table 1. Summary of Rabbits Seen during Roadside Counts

Year	Route	Number of days	Range of number seen		
			Adult	Juvenile	Total*
1958.....	1	6	..	..	6–39
	2	7	..	..	3–41
	3	6	..	..	6–40
1959.....	1	10	13–26	14–37	31–60
	2	10	2–17	10–43	13–50
	3	10	3–16	11–21	17–34
1960.....	1	10	1–30	3–38	4–77
	2	10	0–19	1–33	1–51
	3	10	1–17	0–42	1–60
	4 (run 1)	10	1–11	1– 7	2–23
	(run 2)	10	2–21	3–23	5–53
	(run 3)	10	3–21	1–13	6–38
1961.....	1	5	12–20	14–24	32–42
	2	6	7–17	7–35	21–59
	3	6	2– 9	12–27	17–37
	4 (run 1)	9	2– 7	3–11	7–16
	(run 2)	10	1– 6	6–19	10–26
	(run 3)	10	0– 4	5–17	7–20
1962.....	1	5	10–22	16–44	28–62
	2	6	7–19	12–27	20–47
	3	5	3–16	1–26	5–36
	4 (run 1)	10	1–11	0– 8	3–20
	(run 2)	10	4–16	2–18	8–35
	(run 3)	10	2–13	0–15	3–26
1963.....	1	5	14–20	10–32	31–52
	2	5	4– 8	11–18	17–28
	3	5	5–14	17–27	26–43
	4 (run 1)	8	2–11	2– 7	7–16
	(run 2)	10	2–10	3–14	6–22
	(run 3)	10	0– 6	2– 8	5–15

* Includes rabbits for which age determination was not made.

Temperature

Data pertaining to temperature are given in Table 2. For Routes 1, 2 and 3 in 1958 and 1959 when temperatures at 6 a. m. at the Albany Airport were used, all correlations with the number of rabbits seen were inverse but only that for adult rabbits in 1959 was statistically significant. In 1960, 1961 and 1962 when on-route temperatures at the start were used, one correlation was significant. However, 18 of 27 tests (3 routes × 3 classes of rabbit × 3 years) indicated an inverse relationship. Correlations were weakest in 1961 when starting temperatures were highest and daily variation least.

Data for Route 4 were more definitive. Here again the great majority

TABLE 2. CORRELATION OF RABBITS SEEN WITH TEMPERATURE DURING ROADSIDE COUNTS

Year	Route	Range of temperature § (degrees F.)	Number of days	Correlation (r)		
				Adult	Juvenile	Total
1958....	1, 2 & 3	51–72	5	..	..	−0.51
1959....	1, 2 & 3	59–73	10	−0.64*	−0.08	−0.30
1960....	1	51–64	10	−0.33	−0.27	−0.28
	2	56–71	10	−0.19	−0.21	−0.22
	3	50–73	10	−0.44	−0.20	−0.32
	4 (run 1)	50–67	10	−0.33	−0.27	−0.28
	(run 2)	52–72	10	−0.44	−0.65*	−0.62*
	(run 3)	55–70	10	−0.22	−0.10	−0.22
1961....	1	60–67	5	0.65	−0.20	0.32
	2	64–69	6	0.40	0.79*	0.72
	3	60–75	6	0.48	−0.43	−0.26
	4 (run 1)	63–71	9	−0.38	−0.29	−0.36
	(run 2)	62–71	10	−0.32	0.27	0.08
	(run 3)	65–74	10	0.02	−0.42	−0.38
1962....	1	44–62	5	−0.56	−0.56	−0.67
	2	52–60	6	0.16	0.23	0.02
	3	55–60	5	−0.11	−0.50	−0.42
	4 (run 1)	49–70	9	−0.71*	−0.82**	−0.75*
	(run 2)	52–70	9	−0.44	−0.42	−0.45
	(run 3)	55–71	9	−0.47	−0.56	−0.72*

§ Temperatures for 1958 and 1959 are from U.S. Weather Bureau records for the Albany Airport at 6:00 a.m. E.D.S.T. Those for other years are from on-route observations.
* Significant at 5 per cent level.
** Significant at 1 per cent level.

of tests (24 of 27) indicated that as temperature increased the number of rabbits seen decreased. In six instances the correlation was significant. The three direct correlations (none of which was significant) occurred in 1961 when the maximum daily variation in temperature during any run was only 9° F.

A generally inverse relationship between temperature and rabbits seen was strongly indicated. On Route 4 all the significant correlations occurred when there was a temperature range of at least 14° F. between days. However, when the temperature range was less than 10° F. the relationship tended to become weaker. The effect of early morning temperatures appears rather broad under conditions most often encountered at this time of year.

WIND SPEED

Data pertaining to wind speed are given in Table 3. For Routes 1, 2 and 3 total counts of rabbits in 1958 showed a highly significant inverse

Table 3. Correlation of Rabbits Seen with Wind Speed during Roadside Counts

Year	Route	Range of wind speed§ (m.p.h.)	Number of days	Correlation (r)		
				Adult	Juvenile	Total
1958....	1, 2 & 3	0–10	5	..	..	−0.98*
1959....	1, 2 & 3	0–13	10	−0.38	−0.34	−0.45
1960....	1	0–17	10	−0.61*	−0.59	−0.61*
	2	0–17	10	−0.62*	−0.56	−0.67*
	3	0–17	10	−0.34	−0.46	−0.46
1962....	1	1.0–5.5	5	−0.69	−0.73	−0.88*
	2	1.0–4.0	6	−0.83*	−0.55	−0.95**
	3	1.5–5.5	5	−0.65	−0.29	−0.49
	4 (run 1)	1.0–4.5	10	−0.39	−0.39	0.41
	(run 2)	1.0–4.0	10	−0.38	−0.41	−0.45
	(run 3)	1.0–3.5	10	−0.60	−0.56	−0.73*
	4 (run 1)	0– 8	10	−0.42	−0.46	−0.47
	(run 2)	0–10	10	−0.39	−0.47	−0.48
	(run 3)	0– 8	10	−0.48	−0.58	−0.66*

§ Wind speeds for 1958, 1959 and 1960 are from U.S. Weather Bureau records for the Albany Airport at 6:00 a.m. E.D.S.T. Those for 1962 on Routes 1, 2 and 3 and Route 4 (upper series) are on-route Beaufort scale estimates; those on Route 4 (lower series) are on-route measurements.

* Significant at 5 per cent level.

** Significant at 1 per cent level.

correlation with wind speeds up to 10 m.p.h. The following year, with wind speeds up to 13 m.p.h., correlations were inverse but not statistically significant. In 1960 all relationships were inverse and several were significant. Data for 1961 were not tested because of a lack of range in wind conditions. For 1962, however, comparisons were made on the basis of Beauford wind scale estimates[6]. All correlations were again inverse, and three were significant.

An anemometer used on Route 4 in 1960 was unsatisfactory, and in 1961 wind speeds were not sufficiently varied to warrant testing the data. Counts in 1962 were correlated with measured wind speeds and with Beaufort scale values. All correlations but one were inverse, and that between wind speed and total counts on the third runs was significant.

All the tests indicated that wind exerts a depressing influence on rabbit activity; 10 of 40 correlations were statistically significant. Also, Beaufort

[6] The Beaufort scale is a means of estimating wind speeds on the basis of commonly observed phenomena (i.e., smoke rising straight up, wind felt on face, small branches moving, etc.). The following are mile-per-hour wind speeds corresponding to Beaufort scale values of 0 through 5: 0 (calm) = 0 m.p.h.; 1 (light air) = 1 to 3 m.p.h.; 2 (light breeze) = 4 to 7 m.p.h.; 3 (gentle breeze) = 8 to 12 m.p.h.; 4 (moderate breeze) = 13 to 19 m.p.h.; 5 (fresh breeze) = 19 to 24 m.p.h.

scale estimates appear suitable for measuring wind speed for this purpose. While low winds exert some influence on rabbit activity, a substantial effect is indicated at about 8 m.p.h. or a Beaufort scale value of 3.

Precipitation

In 1959 on Routes 1, 2 and 3, total counts of rabbits on mornings of no precipitation were compared with counts on mornings with any form of precipitation (rain and heavy fog did not occur that year). Counts were higher on mornings of precipitation by a significant margin for adults and by a highly significant margin for juveniles and total numbers. In 1961 heavy fog occurred on four of the 10 mornings, and the total counts were significantly lower than on other mornings; on Route 4 a similar relationship occurred for six of 10 mornings. Perhaps this reflected primarily the relative ability of the observer to see rabbits under these conditions.

Occasional observations indicated that, while very light or sporadic rain had little effect on counts, any substantial rainfall caused a marked reduction in rabbit activity. In the first several years of study, surveys were not made or were discontinued with the advent of any appreciable rain. But, beginning in 1960, routes were surveyed on consecutive mornings regardless of weather conditions. In that year substantial rain fell on two of 10 mornings of survey. The data were too limited for statistical treatment. However, less than 4 per cent of the total number of rabbits observed (35 to 1,020) were seen on those two mornings.

Unfortunately, the several forms of precipitation did not occur with sufficient regularity to provide data that could be tested by conventional means. Therefore, a more tenuous approach was taken. For each route and year from 1959 to 1963 the total number of rabbits seen was tabulated according to the form of precipitation prevailing at the time of observation. Data for days when temperatures were less than 50° F. or higher than 65° F., or when wind speeds were more than 5 m.p.h., were omitted. Then, two forms of precipitation at a time were compared on the basis of how many times the counts under one exceeded those under the other.

For instance, on Route 1 in 1960 total counts when dew was present were 77, 70, 65, 64 and 40, while those when there was no precipitation were 49 and 33. Four counts associated with dew exceeded both counts associated with no precipitation (a value of $4 \times 2 = 8$ for dew), and the lowest count for dew was higher than the lowest for no precipitation. Only one count when there was no precipitation exceeded a count made when dew was present. Thus, in nine of 10 possible comparisons (5 dew $\times$ 2 no precipitation), counts associated with dew were higher. The same comparisons were made for all applicable "route years" (19) and re-

vealed that in the aggregate counts associated with dew were higher in 78 instances and lower in 17.

Similar two-factor comparisons were made for data pertaining to fog, light rain, and simultaneous dew and fog, and the ratios were tested by chi-square (Table 4). For five ratios, the deviation from what would

Table 4. Chi-square Comparisons of Rabbits Seen under Various Forms of Precipitation §

Forms of precipitation compared		Route years	Frequency of higher counts		Chi-square	Probability (per cent)
A	B		Form A	Form B		
Dew.....	None.....	19	78	17	39.2**	<0.005
Dew.....	Fog.....	15	58	15	25.4*	0.032
Dew.....	Dew and fog.	18	45	27	4.6	>0.995
Dew and fog.	None.....	13	21	6	7.2	0.215
Dew and fog.	Fog.....	11	16	10	1.4	>0.995
Dew and fog.	Light rain...	2	1	1	‡	..
Fog.....	None.....	11	11	22	3.7	0.958
Fog.....	Light rain...	4	0	9	9.0*	0.031
Light rain...	None.....	5	4	6	0.4	0.982
Dew†.....	None.....	19	99	27	41.2**	<0.005
Dew†.....	Fog.....	15	78	30	21.4	0.094
Dew†.....	Light rain...	6	15	6	3.8	0.588

§ See text concerning method of analysis.
† Data combined for dew alone and simultaneous dew and fog.
‡ Not tested.
* Significant at 5 per cent level.
** Significant at 1 per cent level.

be expected to occur by chance was significant or nearly significant. On the basis of all comparisons, the various forms of precipitation were ranked as follows in descending order of favorability to the roadside-count technique: dew, dew and fog, light rain, fog, and no precipitation. With moderate to heavy rain added as a still less favorable condition this relationship was generally applicable to data from Route 4 in 1962 and 1963. The validity of this ranking was strongest with respect to counts of adults. For both adults and juveniles correlations were stronger in first and second runs than in third runs.

These findings indicate that various forms of precipitation affect counts of rabbits. Moderate to heavy rain and heavy fog result in much reduced counts. Light to moderate fog has a much lesser effect, while very light rain does not appear to depress roadside rabbit activity. Substantial dew (alone or occurring simultaneously with light to moderate fog) generally coincides with the highest counts, but the absence of any precipitation is unfavorable.

LIGHT INTENSITY

Light intensity was measured only on Route 4. In 1960 readings were made by pointing a photographic light meter toward a given part of the sky, and the same procedure was employed in 1961. In 1962 a photovoltaic cell apparatus was installed at the weather station. Connected to the cell was a Rustrak recorder which provided a continuous graphic record of light measurements. This apparatus was used in 1963 also. The data are given in Table 5; the limited range of light conditions in

TABLE 5. CORRELATION OF RABBITS SEEN WITH LIGHT INTENSITY DURING ROADSIDE COUNTS ON ROUTE 4

Year	Run	Range of light intensity §	Number of days	Correlation (r)		
				Adult	Juvenile	Total
1960.....	1	1– 3	10	0.57	0.63*	0.69*
	2	3– 7	10	0.78**	0.46	0.74**
	3	4– 9	10	0.49	0.52	0.50
1962.....	1	1.5– 4.5	10	0.36	0.67*	0.60
	2	3.0– 9.0	10	0.37	0.51	0.52
	3	3.5–13.5	10	0.40	0.61*	0.64*
1963.....	1	1– 9	8	−0.21	..	..
	2	4–18	9	0.60	..	..
	3	9–15	10	..	..	..

§ Values in 1960 were obtained from a photographic light meter; those in 1962 and 1963 from an automatic recording device employing a light-sensitive photovoltaic cell. They are relative measurements only and bear no numerical relationship to each other or to more common expressions of light intensity such as foot-candles.

* Significant at 5 per cent level.

** Significant at 1 per cent level.

1961 did not warrant statistical treatment. All correlations of light readings and counts of rabbits were positive except for one in 1963. In four instances in 1960 and three in 1962 the relationships were significant. Correlation of light measurements with cloud cover and fog conditions indicated that gross estimates of the latter cannot be easily converted to useful measurements of relative brightness because certain cloud formations reduce light intensity while others increase it.

CLOUD COVER

In 1960 on Routes 1, 2 and 3, and in 1961 and 1962 on Route 4, gross estimates of the extent of cloud cover at the time of survey were recorded. Nine correlations with the total number of rabbits seen resulted in a very erratic pattern; none approached significance. The roadside counts were

also correlated according to various magnitudes of cloud cover on the basis of mean differences, but no significant relationship was indicated

Barometric Pressure

No relationship between daily barometric pressure levels and counts of rabbits was detected. Pressure measurements from the Albany Airport in 1958 and 1959 were correlated with total counts on Routes 1, 2 and 3. Although the pressure varied up to 0.46 inch (in 1959), none of the correlations approached significance. Data for Route 4 in 1960 and 1962 were tested with similar results. In several years counts were compared subjectively with trends in pressure for various periods before, during and after survey. In 1959 the total number of adult rabbits seen on the three routes combined tended to be higher under a steady or falling barometer than during a rise in atmospheric pressure. The rate and direction of atmospheric pressure changes, especially those associated with frontal movements, may be important, but data of this sort do not lend themselves to statistical analysis.

Relative Humidity

Relative humidity at the Albany Airport varied up to 23 per cent in 1958 and 11 per cent in 1959. On Route 4 it varied up to 47 per cent in 1960 and 20 per cent in 1962. But correlations of humidity with the number of rabbits seen did not approach statistical significance. A variety of subjective examinations also failed to suggest any relationship.

Road Wetness

Road surfaces were estimated as being dry, damp or wet. The occurrence of these conditions was correlated with total counts of rabbits on Route 4 in 1960 and 1962. Mean difference in counts did not approach significance.

Time

Survey of Route 4 three times each morning afforded a measure of the relationship of roadside counts to time. Average starting times were as follows: first run, 5:39 a.m.; second run, 6:21 a.m.; and third run, 7:05 a.m. Tests for the difference between means showed that counts on second runs were consistently higher than those on the first or third runs (Table 6). In three or four years, counts on third runs were next highest. These findings indicate that roadside surveys begun after 6:00 a.m. and completed between 7:30 and 7:45 a.m. will result in higher counts than those begun at 5:30 a.m. when daylight generally first becomes sufficient for observations. A 20-mile survey route—the average length recommended for New York—requires about 1½ hours to cover. A starting time of 6:00 to 6:15 a.m. would assure observations during the cotton-

tail's peak period of roadside activity. Therefore, a standard starting time should be adherede to in order for comparisons of counts to be meaningful.

Table 6. Comparison of Different Runs on Route 4 with Respect to the Mean Numbers of Rabbits Seen

Runs compared	Year	Adult		Juvenile		Total	
		Mean numbers	Difference	Mean numbers	Difference	Mean numbers	Difference
1 and 2	1960	6.6 vs. 12.1	5.5*	3.7 vs. 9.7	6.0*	11.8 vs. 25.3	13.5*
	1961	3.9 vs. 3.5	0.4	5.3 vs. 11.8	6.5**	9.8 vs. 16.6	6.8**
	1962	6.0 vs. 8.3	2.3	3.4 vs. 7.9	4.5**	10.9 vs. 17.7	6.8
	1963	4.5 vs. 5.5	1.0	5.1 vs. 9.6	4.5**	10.8 vs. 16.3	5.5**
1 and 3	1960	6.6 vs. 11.4	4.8*	3.7 vs. 7.4	3.7*	11.8 vs. 20.8	9.0*
	1961	3.9 vs. 2.4	1.5*	5.3 vs. 9.3	4.0**	9.8 vs. 12.9	3.1
	1962	6.0 vs. 6.5	0.5	3.4 vs. 4.6	1.2	10.9 vs. 12.6	1.7
	1963	4.5 vs. 3.6	0.9	5.1 vs. 4.8	0.3	10.8 vs. 9.3	1.5
2 and 3	1960	12.1 vs. 11.4	0.7	9.7 vs. 7.4	2.3	25.3 vs. 20.8	4.5
	1961	3.5 vs. 2.4	1.1	11.8 vs. 9.3	2.5	16.6 vs. 12.9	3.7
	1962	8.3 vs. 6.5	1.8	7.9 vs. 4.6	3.3	17.7 vs. 12.6	5.1
	1963	5.3 vs. 3.6	1.7	9.1 vs. 4.7	4.3**	15.4 vs. 9.3	6.1**

* Significant at 5 per cent level.
** Significant at 1 per cent level.

Vehicles and Predators

The effect of vehicles and predators (almost wholly domestic dogs and cats) was examined subjectively. In 1959 the number of vehicles (maximum of six for a single run on one route) encountered during survey was compared with the number of rabbits observed on Routes 1, 2 and 3. A possible effect of automobile traffic on counts on Route 1 was the only relationship indicated. Comparisons were also made on a per-mile basis, but no effects were detected. In 1961 as many as 16 vehicles and 12 predators were encountered on a route during one morning, but no relationship to counts of rabbits was noted. It was standard procedure after encountering another vehicle to wait 3 minutes before continuing the survey. Also, portions of routes consisting of heavily travelled main roads were censused only as traffic permitted.

Discussion

This study was undertaken to determine the effect of certain weather conditions and other environmental factors on early-morning roadside counts of cottontails during midsummer. Such information is needed to help evaluate this technique as a means of assessing annual changes in

cottontail abundance. The results have shown some definite relationships pertaining to precipitation, wind speed and time of day. These findings have been used to refine and standardize the technique. It is recommended that counts be started at 6:00 a.m. but that they not be made on mornings or rain or heavy fog or when winds are 8 m.p.h. or higher.

Findings relating to less pronounced or more gradual effects are not as easily applied. For instance, the inverse relationship between temperature and counts appears too broad to permit more than general inferences. Similarly, counts are generally higher in the presence of some dew or fog than in the absence of any form of precipitation. These types of information might be useful for adjusting counts according to annual differences in weather conditions.

Furthermore, the extent to which procedures that require precise measurement of certain conditions can be incorporated in a survey method to be used by a large number of observers must be considered. Light intensity, variations in which showed some relationship to counts of rabbits, affords an example. A light meter was used to measure the conditions encountered. Also, quite subjective observations of cloud cover and fog were included. At present, some 70 observers throughout the State, many of whom are different from year to year, participate in summer roadside counts of cottontails. To equip such a group with suitable instruments or train them to properly interpret cloud and fog conditions is impractical. In a survey of this sort only those types of information can be included that can be recorded by generally simple procedures. However, making counts on a route over a period of several days when the major weather influences are favorable should compensate to a large degree for variations in other factors.

AGE AND GROWTH OF THE NORTHERN KINGFISH IN NEW YORK WATERS[1]

Richard H. Schaefer Conservation Biologist
New York State Conservation Department

ABSTRACT

Between August 1961 and July 1964, age and growth data were collected from approximately 2,700 northern kingfish sampled by several types of gear at various locations in the waters about Long Island, New York. Scale annuli were identified and, based on their locations on the scales and the time of formation, were considered to be valid indicators of age. Fish lengths were back-calculated and the average growth rates for males and females, as well as the length-weight relationship, were determined. The size and age composition of the catches by the different types of gear are presented and discussed. Some observations on age at maturity and mortality rates are included.

The northern kingfish *(Menticirrhus saxatilis)* occurs in the New York area from late April through October. While in this vicinity, these fish are harvested in small quantities by both commercial and sport fisheries. The annual commercial catch has not exceeded 85,000 pounds since 1939 and, more recently, has been less than 5,000 pounds (Table 1). The sport catch, although more difficult to estimate, was reported by Briggs (1962) for the Great South Bay area of Long Island for the years 1956 to 1960. He showed that, although the catch did not exceed 6,650 kingfish (0.2 per cent of the total sport catch) in any one year, it was one of the species most frequently sought after and taken by surf anglers during the summer. Indeed, his data revealed that, during July from 1957 to 1960, kingfish comprised 57 to 77 per cent of the catch of surf anglers between Jones Inlet and Fire Island Inlet. It would appear from these observations that the northern kingfish is very important to the surf sport fishery on Long Island's southern shore.

The present study was prompted by the general lack of information concerning the species and its apparent value to the surf sport fishery. The literature contained little concerning certain aspects of the life history of the fish, i.e., its rate of growth, longevity, mortality, etc. Although spawning and early development were described in some detail by Welsh and Breder (1923) and Hildebrand and Cable (1934), information on growth of northern kingfish beyond 3 months of age was almost totally lacking. Nichols and Breder (1926), Hildebrand and Schroeder (1928), and Bigelow and Schroeder (1953), had also reported on the species but provided little additional knowledge about postjuvenile growth. Aside from collections of eggs and larvae by Perlmutter (1939), and of juveniles by Bean (1903), Greeley (1939) and Gordon (1949), no previous investigations had been conducted on the northern kingfish

[1] A contribution of Federal Aid in Fish and Wildlife Restoration Project F-15-R.

Table 1. Commercial Catch of Northern Kingfish in New York Waters, 1939–1963 *

Year	Pounds
1939	84,300
1940	82,100
1941	no data
1942	24,900
1943	45,500
1944	61,900
1945	41,100
1946	43,500
1947	20,700
1948	16,800
1949	33,800
1950	19,300
1951	13,900
1952	14,300
1953	2,100
1954	3,596
1955	11,950
1956	10,900
1957	4,950
1958	600
1959	2,000
1960	2,300
1961	3,300
1962	1,900
1963	1,800

* Source: Fishery Statistics of U. S. Dept. Interior.

in New York. The present paper is concerned primarily with the age and growth of the species in Long Island waters.

METHODS AND MATERIALS

Age and growth data were collected during the general period of August 1961 through July 1964. Specimens were obtained by haul seining in the bays and ocean and by sampling the catches of sport and commercial fishermen.

Juvenile kingfish were collected at Mercer's Island in Great South Bay and near the mouth of Red Creek Pond in Great Peconic Bay from July through September of the years 1962 and 1963. The sampling gear was a 6 x 300-foot nylon beach seine comprised of 1½-inch stretch mesh in the outer section of the wings, ¼-inch knotless mesh in the inner section of the wings, and ⅛-inch knotless mesh in the "pocket" or cod end. Specimens were collected on a biweekly schedule, and usually four or five seine hauls were made during each sampling trip. Each kingfish captured was measured to the nearest 5 millimeters total length. About 25 to 30 scales were removed from each fish and placed in a labeled coin envelope for future examination.

Early in the study scales were removed from various body regions of a small series of adult and juvenile specimens. Microscopic examination indicated that circuli counts were highest, annuli were clearly distinguishable, and scales were most uniform in size when taken from the caudal peduncle above the lateral line. Thereafter, all scale samples were removed from this area on the left side of the body.

Adult (and some juvenile) kingfish were collected from the ocean surf near Smith Point County Park on Great South Beach from August through October in 1961, from May through October in 1962 and 1963, and from May through July in 1964. The sampling gear used at this location was a modified 1,300-foot commercial nylon ocean seine comprised of 3-inch stretch mesh in the outer section of the wings, 2-inch stretch mesh in the inner section of the wings, and 1⅛-inch stretch mesh in the cod end. With this net and a 21-foot Lowell Banks dory, ocean seining operations were conducted on a daily (weekday) schedule unless prevented by unfavorable weather or surf conditions. Usually two seine hauls were made per day. All kingfish collected by this gear were also measured to the nearest 5 millimeters total length and weighed. A sample of the scales was removed from each fish, and the gonads were examined to determine sex and stage of maturity.

In addition, kingfish were sampled from the sport fishery in the general area between Jones Inlet and Fire Island Inlet from May through October in 1962 and 1963 and from a commercial gill net (3¼-inch stretch nylon mesh) operated in Great South Bay during August and September in 1961. Samples were collected at random from sport catches at the surf and on the fishing piers at Jones Beach and Captree State Parks. When possible, all kingfish in an individual sport catch were examined. The entire gill net catch was sampled. Data similar to those recorded for the ocean-seine collections were recorded for both the sport and gill net catches.

At the laboratory, some eight to ten scales were selected from each scale sample and mounted on 0.05-inch transparent cellulose acetate. Using a Carver Laboratory Press (Model B), scale impressions were made on the acetate. The impressions were viewed at a magnification of 40× on an Eberbach Reflex Micro Projector, and ages were determined. Single scales were chosen at random from each sample for measurement. The distances from the focus to each annulus and to the anterior scale edge (measured along the antero-posterior scale axis) were measured directly on the viewing screen with a standard millimeter rule. The fish length-scale length relationship was then determined by regression analysis. Lengths at previous ages were back-calculated and a growth equation was fitted to the data.

Kingfish were weighed to the nearest 25 grams on a 2,000-gram-

capacity Chatillon spring balance. The weight of each fish was recorded with its corresponding length. These data were also subjected to regression analysis.

Mortality estimates were made based on the age composition of samples taken by ocean seine from May through July.

SCALE GROWTH AND ANNULUS FORMATION

The criteria used for identifying annuli on scales were identical to those used by Joseph (1962) in his study of the California corbina (*Menticirrhus undulatus*). The scales of this species are very similar to those of the northern kingfish. Figure 1 shows typical northern kingfish scales having one, two and three annuli.

Scales were assigned to an age class according to the number of annuli on the scale and the time of year it was collected. One year of age was allocated for each annulus. Furthermore, if a scale collected in spring or summer did not indicate the formation of a new marginal annulus, then it was arbitrarily assigned an additional annulus and placed in the next higher age class. Determination of whether or not the marginal annulus was, in fact, the annulus of the current year or of the preceding year was based largely upon the width of the growth increment between this annulus and the scale edge. If the increment was large, it was assumed that the annulus of the year had not been formed; if the increment was small, it was assumed that the annulus of the year had already been formed. In this manner it is believed that fish collected during the spring and summer were correctly assigned to their respective age classes. Inability to collect sufficient scale-length data from adult kingfish in any single year necessitated combining these data for several different years.

The data are presented in Figures 2 to 6 as frequency distributions of the distances from the focus to each annulus and from the focus to the margin of the scale for various age classes. Figure 2 suggests that annulus formation in yearling kingfish first became evident in June and was completed by August. Only 18 of 96 yearlings sampled in June had an annulus, but it was present in 45 of 50 sampled in July and in all fish sampled in August. Furthermore, the annular distances for scales of yearlings sampled from June through October closely overlapped the marginal distances for scales of yearlings sampled in May and for scales of young-of-the-year fish sampled during September and October (Figure 3). This would indicate that, following rapid early development (Figures 4 and 5), scale growth was considerably reduced during the winter and that the first annulus was formed on the margin of the accrued growth of young-of-the-year fish. Rapid scale growth was resumed following the time of annulus formation, as suggested by the

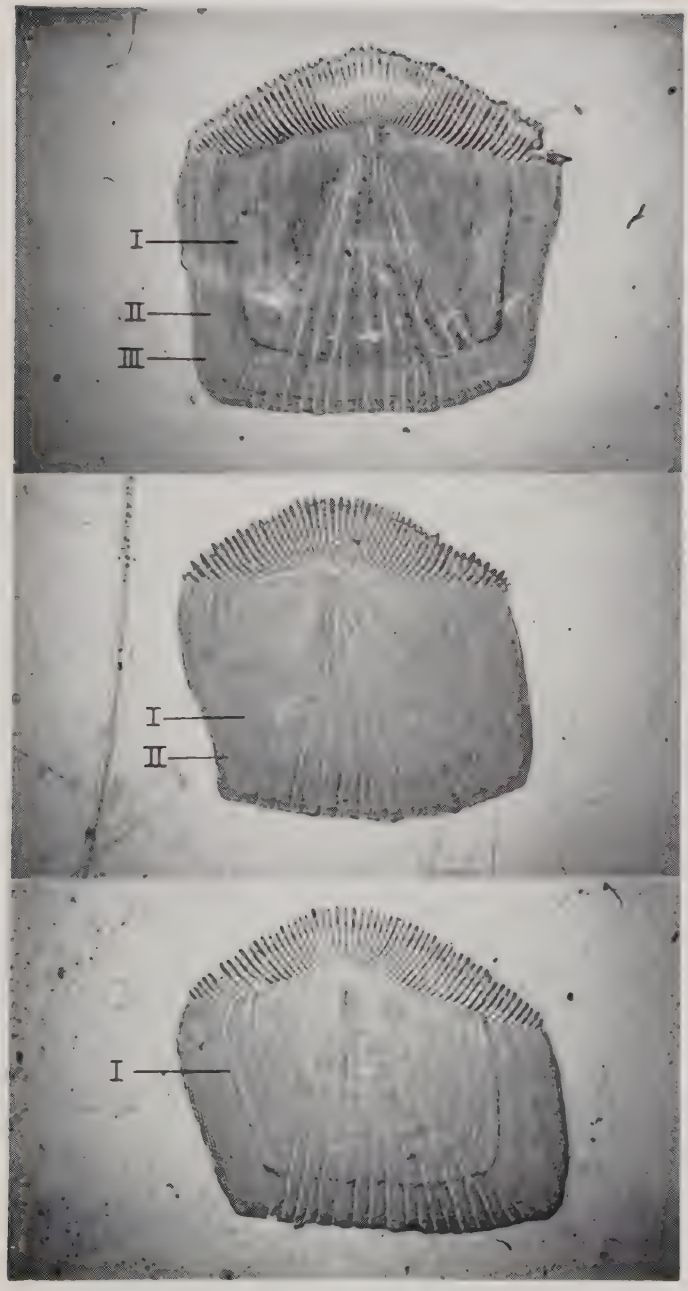

Figure 1. Typical scales from northern kingfish
Upper: from 355-millimeter female taken May 11, 1964, showing one annulus.
Middle: from 350-millimeter male taken May 11, 1964, showing two annuli.
Lower: from 350-millimeter male taken September 16, 1961, showing three annuli.

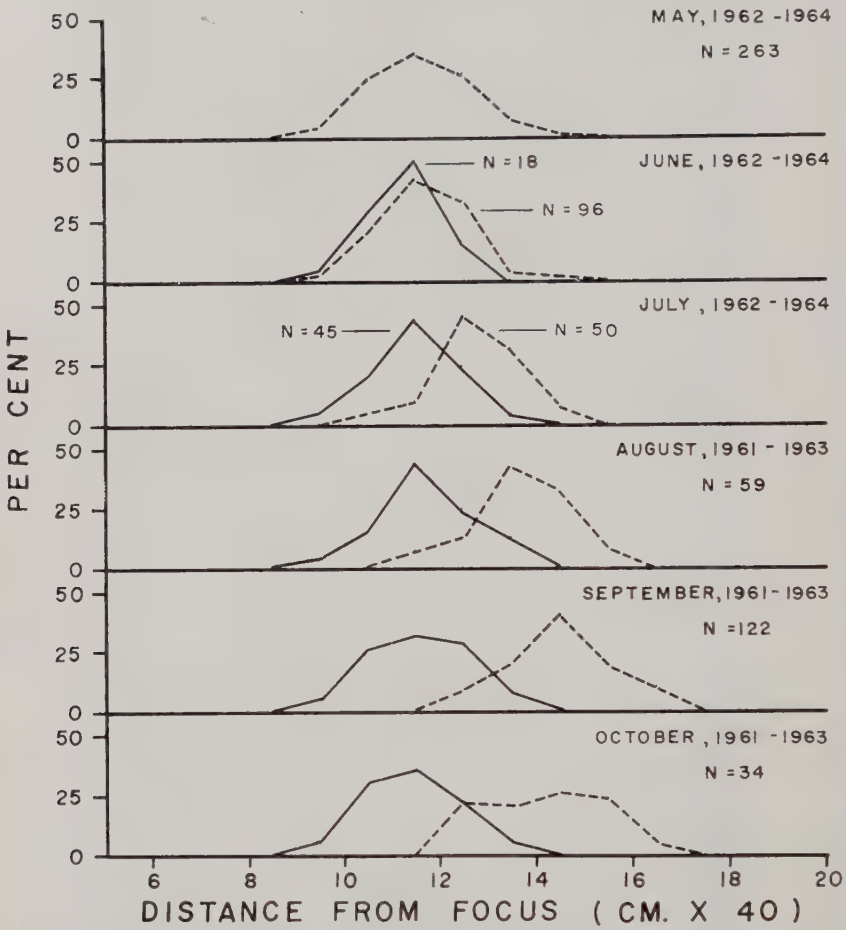

Figure 2. Monthly frequency distributions of distances from focus to annulus (solid lines) and to anterior margin (broken lines) of scales from yearling northern kingfish collected throughout the study.

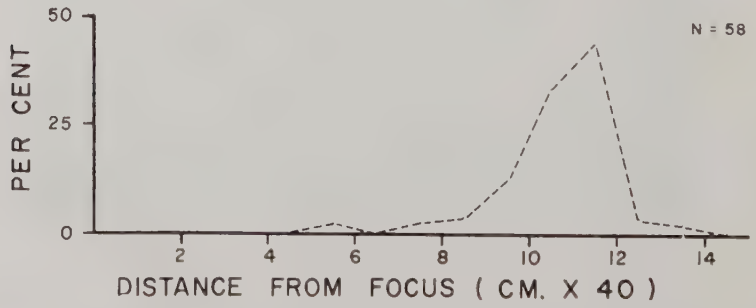

Figure 3. Frequency distribution of distances from focus to anterior margin of scales from young-of-the-year northern kingfish taken by sport fishing during September and October from 1961 to 1963.

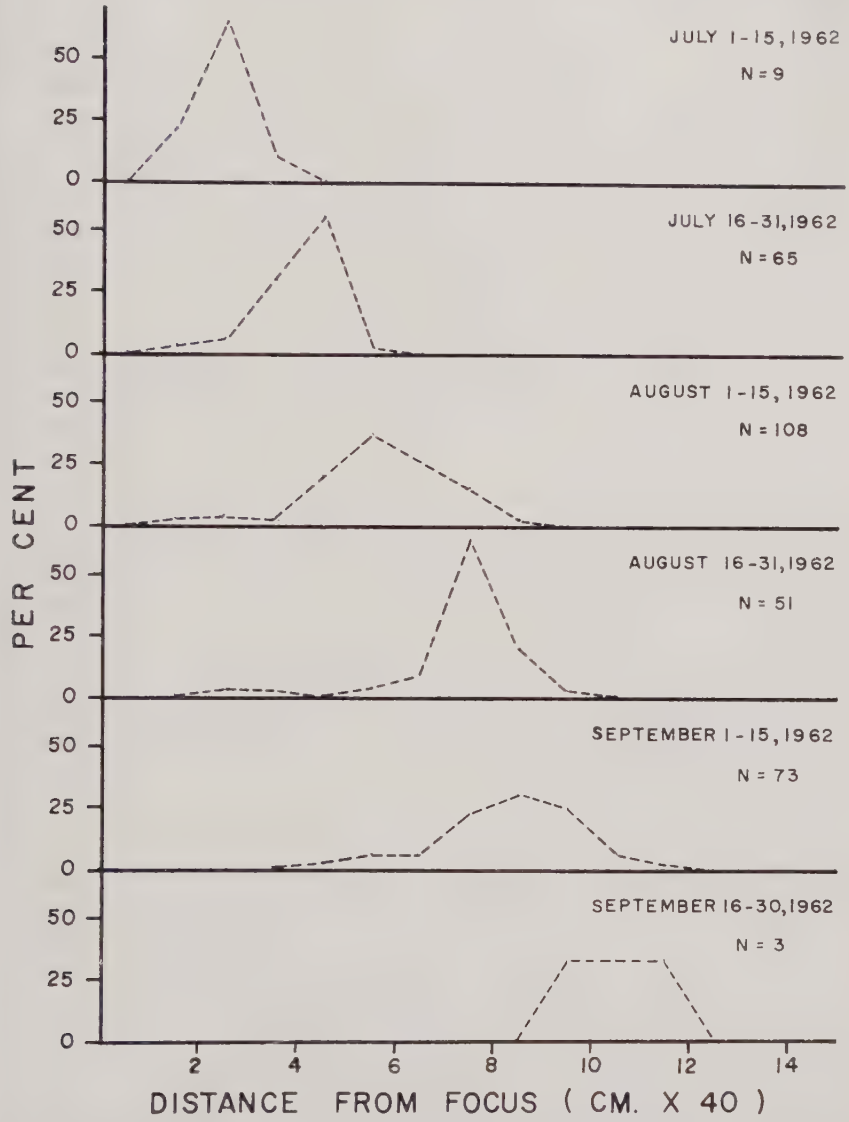

Figure 4. Semimonthly frequency distributions of distances from focus to anterior margin of scales from young-of-the-year northern kingfish collected at Red Creek Pond in Great Peconic Bay between July 1 and September 30 in 1962.

increase in marginal distances from July through October. Similar observations were reported by Pacheco (1962) for the spot (*Leiostomus xanthurus*) and by Massmann (1963) for the weakfish (*Cynoscion regalis*).

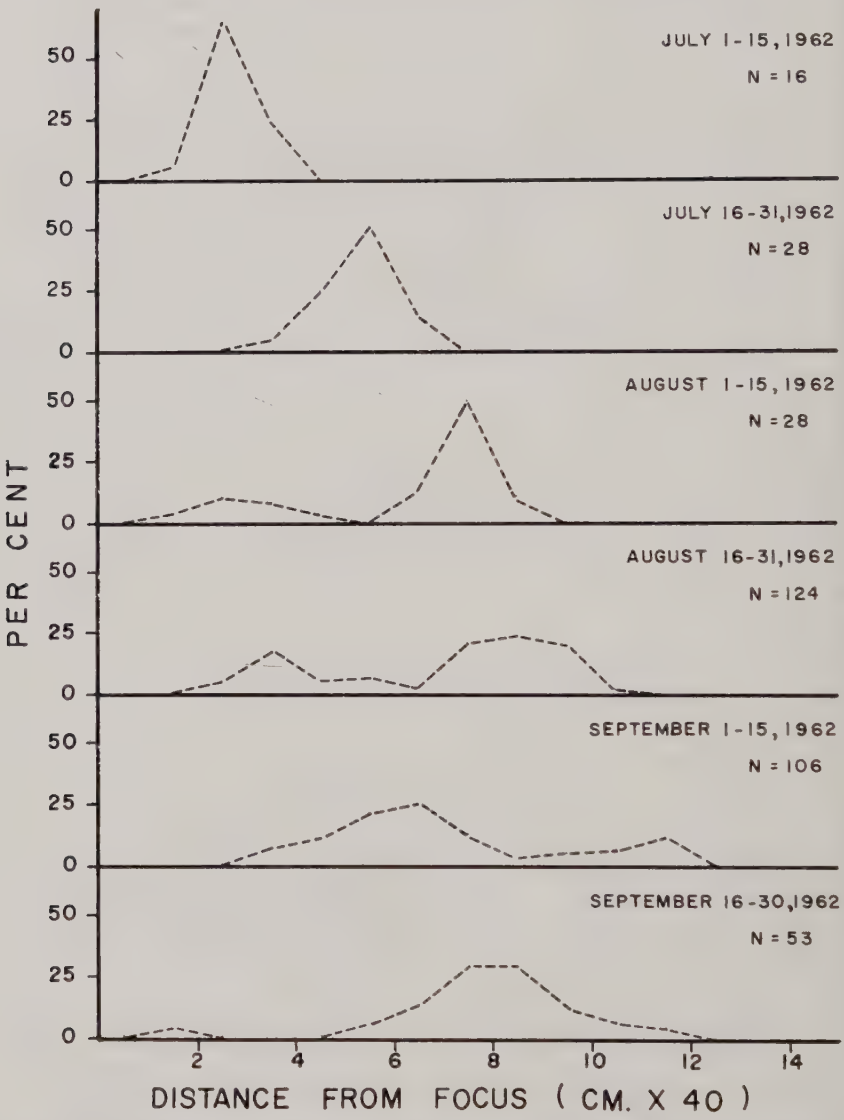

Figure 5. Semimonthly frequency distributions of distances from focus to anterior margin of scales from young-of-the-year northern kingfish collected at Mercer's Island in Great South Bay between July 1 and September 30 in 1962.

Annulus formation appears to have occurred slightly later in 2-year-old fish (Figure 6). None of the 2-year-olds sampled in June had formed a second annulus. However, 21 of 24 fish sampled in July, and 45 of 50 sampled in August, had a well defined second annulus near the

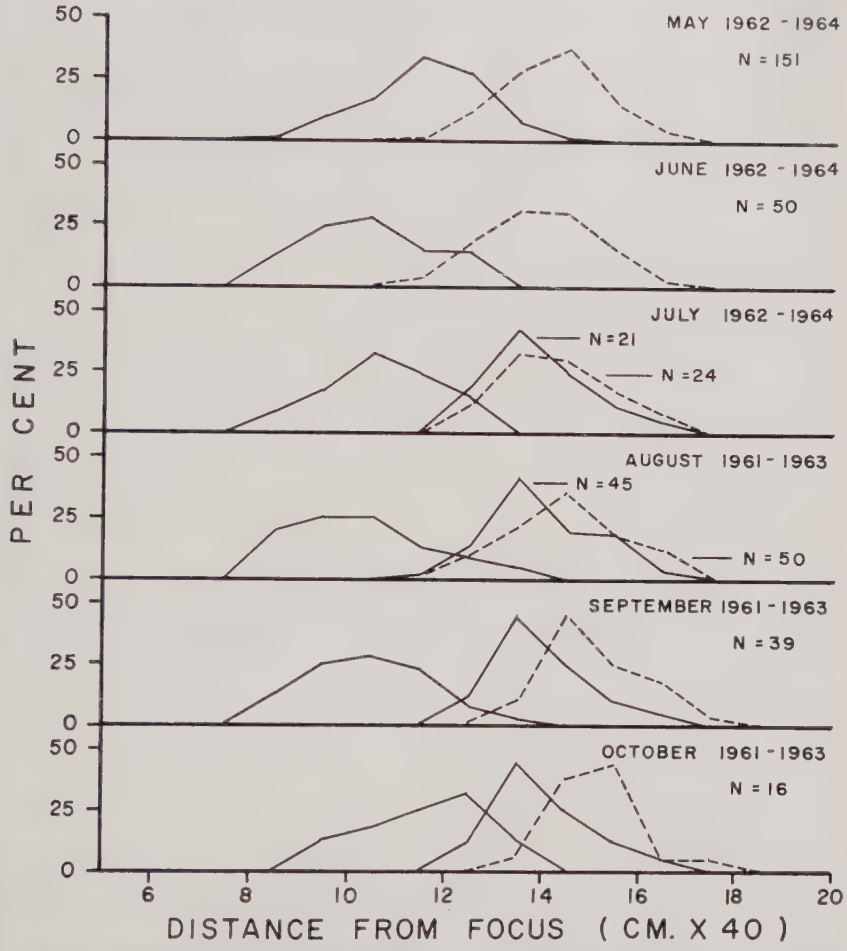

Figure 6. Monthly frequency distributions of distances from focus to annuli (solid lines) and to anterior margin (broken lines) of scales from 2-year-old northern kingfish collected throughout the study.

scale edge. By September all 2-year-old fish had formed the new annulus. Distances from the focus to the second annulus for scales sampled from July through October corresponded well with the marginal distances for scales sampled from 2-year-olds in May and June and from yearlings sampled in October (Figure 2). These data also suggest that scale growth was curtailed during the winter and that the annulus was formed on the margin of the growth increment laid down in the preceding year. Although scale growth was resumed following formation of the second annulus (as indicated by the slight modal increase in the marginal distances for scales of 2-year-olds sampled from August through October), it was apparently at a much reduced rate in com-

parison with the scale growth that followed formation of the first annulus.

Similar data for scales of older kingfish were insufficient for analysis. However, it seems reasonable to conclude from the data presented that, since annuli were formed at approximately the same time of year in two different age groups and were located on the margin of each preceding year's scale growth, scale annuli are true year marks and can be used as valid indicators of age.

Fish Length-Scale Length Relationship

In order to determine the lengths of fish at the time of annulus formation, it was necessary to calculate the fish length-scale length relationship. The general linear function, where

$$X_1 = a + b_{12}X_2$$

was fitted to 1,457 paired observations by the method of least squares. The resulting equation

$$X_1 = 0.983 + 0.039X_2$$

is presented in Figure 7. A correlation coefficient (r_{12}) of 0.974 was obtained, indicating a high degree of relationship between the two variables. An analysis of variance (Table 2) suggested that the relation-

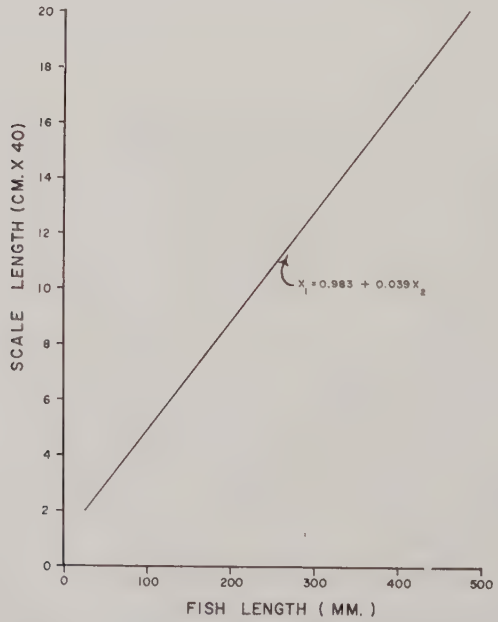

Figure 7. Relationship of fish length to scale length for 1,457 northern kingfish.

TABLE 2. ANALYSIS OF VARIANCE OF FISH LENGTH-SCALE LENGTH LINEAR REGRESSION

Source of variation	Degrees of freedom	Sum of squares	Mean square	Value of F	F (.01)
Total	1,456	23,706.02			
Regression	1	22,501.35	22,501.35	27,110.06**	6.64
Deviations from regression	1,455	1,204.67	0.83		

** Significant at 1 per cent level.

ship did not differ significantly from linearity and was best described by the straight line function.

AGE-LENGTH RELATIONSHIP

Using the formula

$$L_n = C + \frac{S_n (L_t - C)}{S_t}$$

where,

L_n = length of fish at time of formation of n^{th} annulus
L_t = length of fish at time of capture
S_n = distance from focus of scale to n^{th} annulus
S_t = distance from focus of scale to anterior margin
C = The X-axis intercept of the function which describes the fish length-scale length relationship ($C = -24.99$)

fish lengths at previous ages were back-calculated for 227 male and 309 female northern kingfish. These data are presented in Table 3. The apparent differences between the sexes were tested by analysis of variance (Table 4) and found to be significant. Therefore, the von Bertalannfy growth-in-length function

$$L_t = L_\infty \left[1 - e^{-k\ (t_n - t_o)} \right]$$

where,

L_t = length at age t
L_∞ = maximum expected length (asymptote)
k = constant which is proportional to the rate of destruction of body materials
t_o = hypothetical age at 0 length
t_n = age of fish in the n^{th} age group, where $t_1 = 0$

was fitted separately to the data for each sex by the method of least squares as described by Tomlinson and Abramson (1961). The resulting functions

$$\text{males: } L_t = 386.6\left[1 - e^{-0.7014\ (t_n + 0.5505)}\right]$$

$$\text{females: } L_t = 447.5\left[1 - e^{-0.5558\ (t_n + 0.6186)}\right]$$

are presented graphically in Figure 8 and indicate that male and female northern kingfish attained respective average sizes of 256.3 and 265.5 millimeters at age I, 322.0 and 343.1 millimeters at age II, 354.6 and 387.6 millimeters at age III, and 370.7 and 413.1 millimeters at age IV.

Table 3. Frequency Distributions of Back-Calculated Lengths at Previous Ages for 536 Northern Kingfish Sampled Between August 1, 1961 and July 31, 1964

Total length (millimeters)	Age group and sex							
	I		II		III		IV	
	Male	Female	Male	Female	Male	Female	Male	Female
170–179	1	1	..	..	..	..	..	..
180–189	5	5	..	..	..	..	..	..
190–199	5	11	..	..	..	..	..	..
200–209	10	4	..	..	..	..	..	..
210–219	14	12	..	..	..	..	..	..
220–229	16	14	..	..	..	..	..	..
230–239	22	23	..	..	..	..	..	..
240–249	29	25	..	..	..	..	..	..
250–259	15	30	..	..	..	..	..	..
260–269	23	45	2	..	..	..	..	..
270–279	26	35	2	..	..	..	..	..
280–289	24	34	3	..	..	..	..	..
290–299	21	38	1	9	..	..	..	..
300–309	11	15	9	4	..	..	..	..
310–319	5	10	5	7	..	..	..	..
320–329	..	6	11	6	1	1	..	..
330–339	..	1	6	5	..	..	..	..
340–349	..	..	6	11	..	..	..	..
350–359	..	..	3	8	1	..	..	..
360–369	..	..	2	7	..	..	1	..
370–379	..	..	..	4	..	..	..	1
380–389	..	..	1	2	1	..	..	..
390–399	..	..	..	3	..	..	..	..
400–409	..	..	..	..	..	..	..	..
410–419	..	..	..	..	..	1	..	..
420–429	..	..	..	..	..	1	..	..
430–439	..	..	..	..	..	..	..	..
440–449	..	..	..	..	..	..	..	..
450–459	..	..	..	..	..	..	..	1
Number	227	309	51	66	3	3	1	2
Mean length	256.5	265.6	321.0	342.8	356.2	388.1	369.9	413.0

TABLE 4. ANALYSIS OF VARIANCE OF AGE-LENGTH DATA FOR NORTHERN KINGFISH

Source of variation	Degrees of freedom	Sum of squares	Mean square	Value of *F*	*F* (.01)
Total	563	1,111,231.3			
Age	3	521,461.0	173,820.3	171.70*	3.78
Sex	1	21,397.1	21,397.1	21.14*	6.64
Age vs. sex interaction	3	5,595.7	1,865.2	1.84	3.78
Within subclasses	556	562,777.5	1,012.2		

*Significant at 1 per cent level.

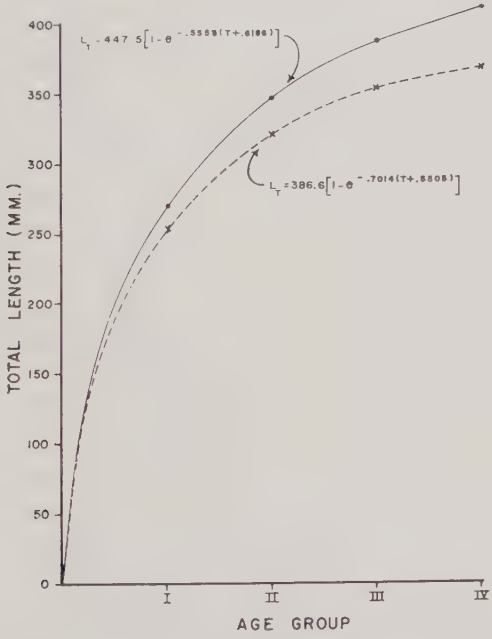

Figure 8. Growth rates of male (broken line) and female (solid line) northern kingfish computed from back-calculated lengths at previous ages in Table 3.

The maximum average expected sizes were 386.6 millimeters for males and 447.5 millimeters for females based on the foregoing growth curves. It was determined from these observations that males and females, respectively, attained 66.3 and 59.3 per cent of their maximum ex-

pected lengths by age I, 83.3 and 76.7 per cent by age II, 91.7 and 86.6 per cent by age III, and 95.9 and 92.3 per cent by age IV.

Length-Weight Relationship

The general empirical length-weight function, where

$$W = aL^b$$

or, in logarithmic form,

$$\log W = \log a + b \log L$$

was fitted separately to the data for 216 males and 275 females by the method of least squares. The computations yielded the following regression equations

$$\text{males:} \quad \log W = -5.3905 + 3.1602 \log L$$
$$\text{females:} \quad \log W = -5.0491 + 3.0261 \log L$$

A t-test conducted on the regression coefficients (b_1, b_2), however, indicated that there was no significant difference between the slopes of the two lines of regressions ($t_{b_1-b_2} = 1.56$, d.f.$=487$). The data were, therefore, combined and a new equation

$$\log W = -5.1737 + 3.0747 \log L$$

was computed. This relationship between length and weight ($r = 0.959$) is presented graphically in Figure 9.

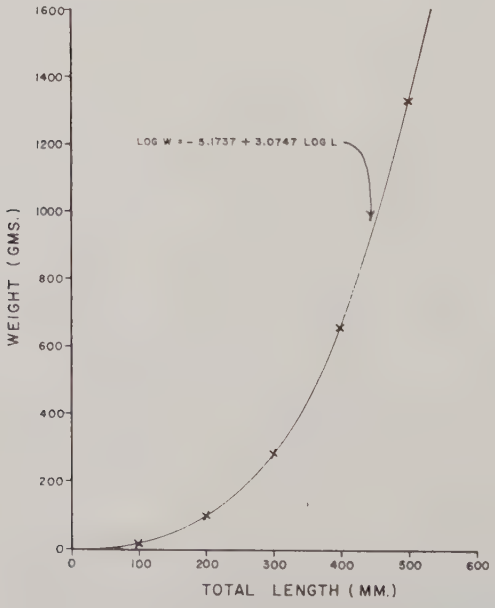

Figure 9. Length-weight relationship for 491 northern kingfish (sexes combined).

LENGTH AND AGE COMPOSITION OF THE CATCH

Data for length and age were analyzed separately for samples taken by seining in Great South Bay and Great Peconic Bay, by seining in the ocean surf at Great South Beach, by sport fishing in the surf and on the piers from Jones Inlet to Fire Island Inlet, and by commercial gillnetting in Great South Bay.

CATCH BY SEINING IN BAY AREAS

All northern kingfish captured with the 300-foot bay seine at Red Creek Pond in Great Peconic Bay and at Mercer's Island in Great South

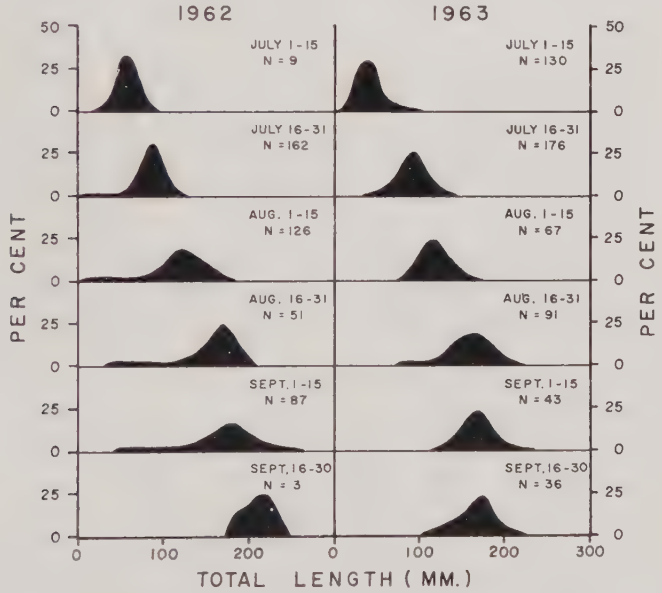

Figure 10. Semimonthly length-frequency distributions of young-of-the-year northern kingfish collected at Red Creek Pond in Great Peconic Bay during 1962 and 1963.

Bay were found to be age 0. Semimonthly length-frequency distributions (smoothed once by threes) of the fish collected during the summers of 1962 and 1963 are presented in Figures 10 and 11.

Specimens were first collected in early July each year. The combined data from both bays and both years indicate a size range for age 0 fish of 25 to 125 millimeters with an average of 76 millimeters in July, 25 to 225 millimeters with an average of 141 millimeters in August, and 45 to 265 millimeters with an average of 166 millimeters in September. Although sampling was continued through October at these locations,

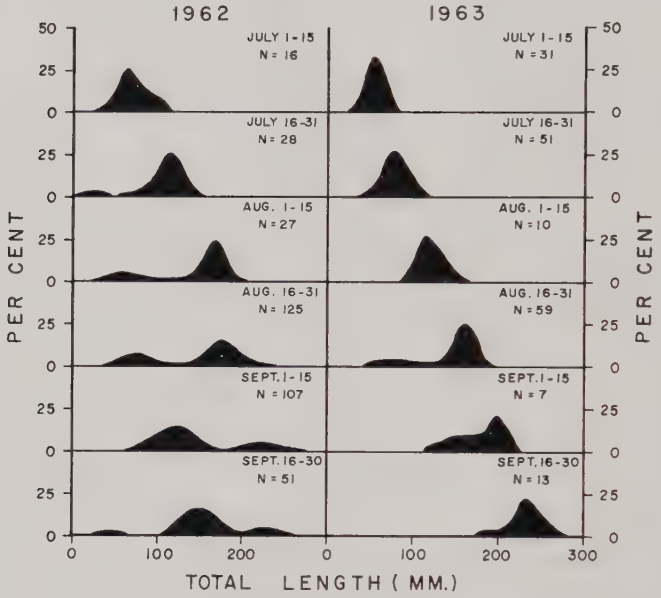

Figure 11. Semimonthly length-frequency distributions of young-of-the-year northern kingfish collected at Mercer's Island in Great South Bay during 1962 and 1963.

too few examples were collected during that month to warrant including the data in the graphs. Data from all sources, however, indicate that young of the year ranged in size from 25 to 315 millimeters with an average of 202 millimeters in October (Figure 12).

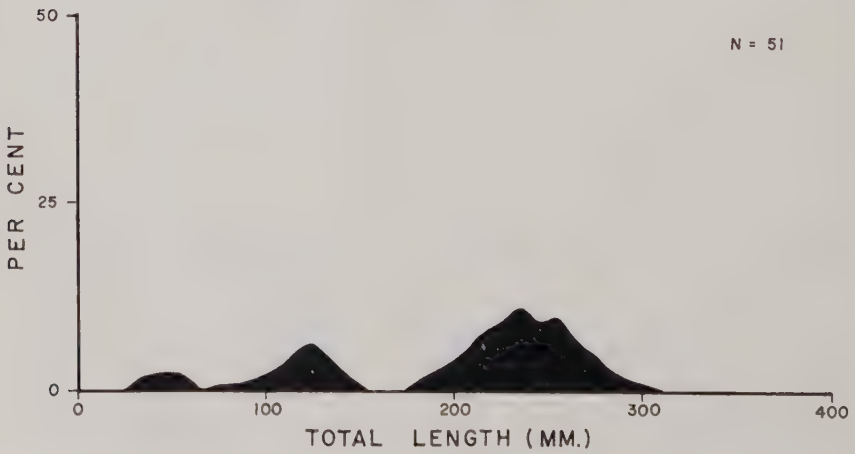

Figure 12. Length-frequency distribution of young-of-the-year northern kingfish collected from all available sources during October in 1962 and 1963.

In addition to an increase in size range and average size as the season advanced, there was also an increase, in some cases, in the number of length modes. It is apparent from Figures 10 and 11 that the length-frequency distribution in early July was unimodal. However, for fish collected at Mercer's Island in 1962, the distribution from late July through early September was essentially bimodal and, by late September, had even become trimodal. The pattern for data from Red Creek Pond during the same year and from Mercer's Island in 1963 exhibited a similar but less well defined trend. The increase in the number of length modes was apparently due to protracted spawning which resulted in more or less continuous recruitment of newly hatched fish into the juvenile population throughout the summer.

Catch by Seining in the Ocean Surf

The catch with the 1,300-foot ocean seine near Smith Point County Park on Great South Beach was arbitrarily divided according to early (May 1-July31) and late (August 1-October 31) collecting periods to illustrate differences in length and age composition as the season advanced. The data are presented in Figures 13 and 14.

It is apparent that the length-frequency distribution during the early period (Figure 13) was generally bimodal and that the catch was composed primarily of two age classes, i.e., 1- and 2-year-old fish. These

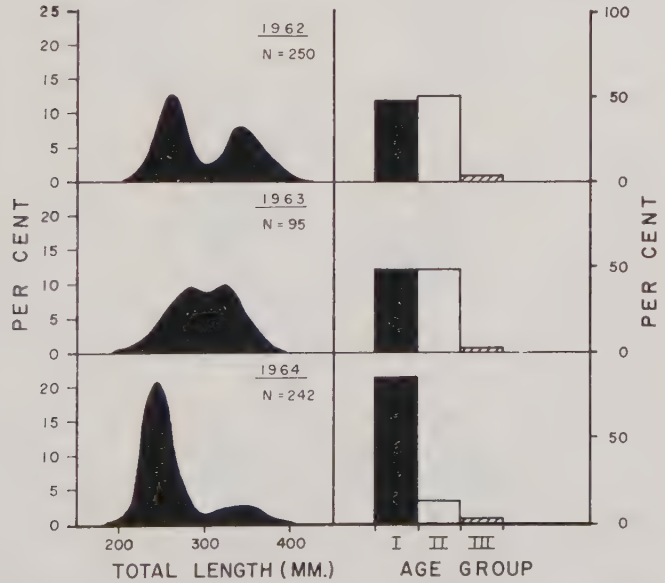

Figure 13. Length- and age-frequency distributions of northern kingfish collected by ocean seine between May 1 and July 31 from 1962 to 1964.

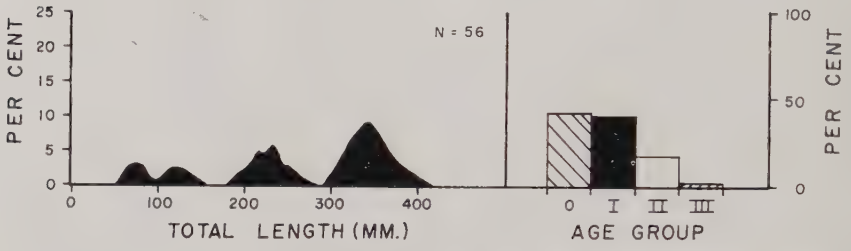

Figure 14. Length- and age-frequency distributions of northern kingfish collected by ocean seine between August 1 and October 31 in 1962 and 1963.

two groups combined never constituted less than 95 per cent of the specimens taken at any time during the early period for the years 1962 to 1964. Three-year-olds, the oldest age group taken, consistently represented less than 5 per cent of the total catch, and young-of-the-year fish were entirely absent.

During the late collecting period, however, young-of-the-year fish represented approximately 42 per cent of the catch (Figure 14). Correspondingly, 1- and 2-year-old fish together formed less than 60 per cent while 3-year-olds remained at less than 5 per cent of the catch.

Catch by Sport Fishing

The catch by sport fishing in the surf and on the piers from Jones Inlet to Fire Island Inlet was sampled according to the same early and

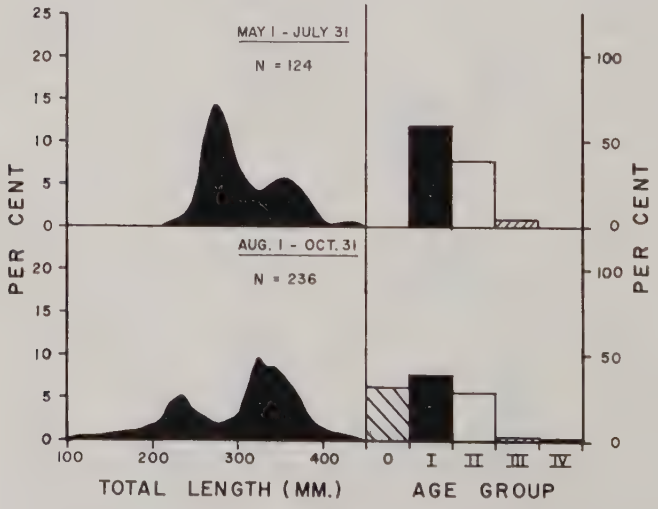

Figure 15. Length- and age-frequency distributions of northern kingfish taken by sport fishing between May 1 and July 31 and between August 1 and October 31 from 1961 to 1963.

late periods as were used for the catch by seining in the ocean surf. The combined data for both years on length and age are presented in Figure 15.

The results were similar to those for the ocean seine catch. The length frequency for the early period was generally bimodal, and the samples were composed primarily of 1- and 2-year-old fish. These two age groups represented approximately 95 per cent of the sport catch during this period. Three-year-olds comprised less than 5 per cent of the catch and young of the year were entirely absent.

In the late collecting period, however, the length and age composition was considerably altered. One- and 2-year-old fish represented less than 70 per cent of the catch, and young of the year entered into the fishery. The latter comprised approximately 30 per cent of the catch while 3-year-old and older fish remained at less than 5 per cent.

Catch by Commercial Gillnetting

One- and 2-year-old fish comprised nearly all of the samples taken by commercial gillnetting in Great South Bay during August and September of 1961 (Figure 16). One-year-olds were dominant (78 per

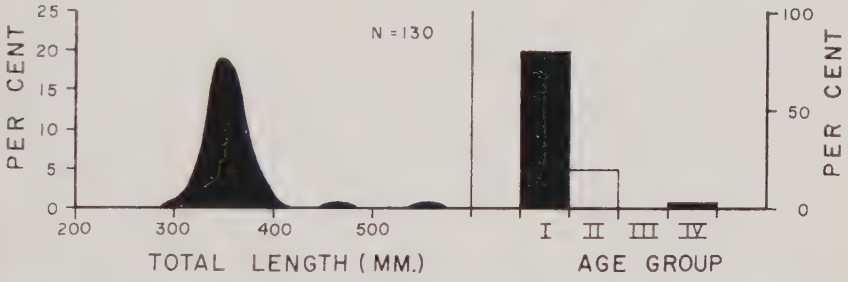

Figure 16. Length- and age-frequency distributions of northern kingfish collected by commercial gillnetting in Great South Bay during August and September in 1961.

cent), while fish 3 years of age or older represented only about 3 per cent of the total catch. No young-of-the-year fish were taken, probably because of the large mesh size of the sampling gear.

The largest northern kingfish collected during the present study, and possibly the largest ever recorded anywhere, was captured by this gear. It was a 550-millimeter (21.7-inch) female in its third summer of life and weighed 1,500 grams (3.3 pounds). Although a few authors have reported the species as attaining a weight of 6 pounds (Nichols and Breder, 1926; LaMonte 1950, 1952), records of fish of this size are not specific and appear to lack authenticity. Most authors have given 2 or 3 pounds as the maximum weight and 17 or 18 inches as the maxi-

mum length (DeKay, 1842; Bean, 1901, 1903; Hildebrand and Schroeder, 1928; Breder, 1948; Bigelow and Schroeder, 1953; Perlmutter, 1961). Latham (1923) reported that the largest northern kingfish ever obtained by him at Orient, New York, weighed 2 pounds and was 16¾ inches in length.

MORTALITY

Estimates of the annual mortality rate were computed from the age-frequency data for the ocean seine catches made during the early collecting periods for the years 1962 through 1964 (Figure 13). Assum-

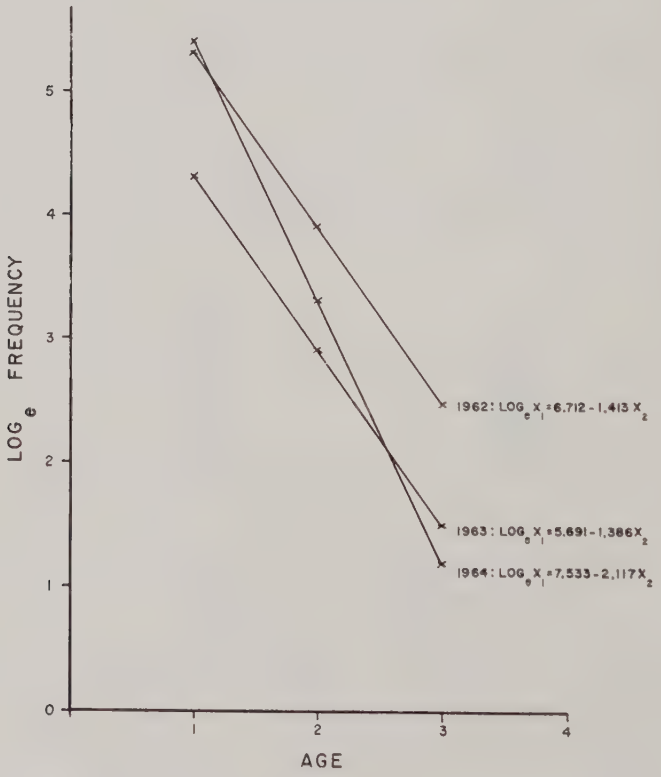

Figure 17. Regression lines relating logarithms of age frequency to age for northern kingfish collected by ocean seine between May 1 and July 31 from 1962 to 1964 (Figure 13).

ing that the basic requirements for using the catch-curve method of estimating mortality (Rounsefell and Everhart, 1953; Ricker, 1958; Robson and Chapman, 1961) were satisfied, frequencies at each age

were converted to natural logarithms and the data were subjected to regression analysis. The linear function

$$\log_e X_1 = a - bX_2$$

was fitted to each year's data with the following results

1962: $\log_e X_1 = 6.712 - 1.413X_2$ $(r_{12} = 0.901)$
1963: $\log_e X_1 = 5.691 - 1.386X_2$ $(r_{12} = 0.879)$
1964: $\log_e X_1 = 7.533 - 2.117X_2$ $(r_{12} = 0.998)$

These equations are plotted in Figure 17.

Since the regression coefficients (b) in the foregoing equations are estimates of the instantaneous rates of mortality, the annual mortality rates (m) can be estimated from the formula

$$m = 1 - e^b$$

Substituting the regression coefficients in this equation, the estimated annual mortality rates were

1962: $m = 1 - e^{-1.413} = 0.76$
1963: $m = 1 - e^{-1.386} = 0.75$
1964: $m = 1 - e^{-2.117} = 0.88$

Because of the limited number of age groups represented in the age-frequency distributions, only one of the three regression equations (that for 1964) was found to fit the data significantly ($t_b = 14.68$). It was impossible, therefore, to test for significant differences between the slopes of any of the mortality regressions. It seems clear, however, that these slopes approximated each other closely enough to suggest that the true mortality rate is apparently very high.

AGE AT MATURITY

Some observations on the age of kingfish at maturity were made based on gross examination of the gonads from fish taken by ocean seine at Great South Beach during May and June of 1963 and 1964. The gonads were separated into three categories, i.e., unripe, ripening and running ripe. Males were classified as: unripe if the testes were thin and translucent white to light pink in color, and if no milt could be extruded from the vent under heavy pressure; ripening if the testes were slightly enlarged or swollen and opaquely white in color, and if some milt could be extruded from the vent under medium pressure; running ripe if the testes were greatly enlarged and swollen and opalescent white in color, and if milt flowed freely from the vent under slight or no pressure. Similarly, females were classified as: unripe if the ovaries were thin, pink to pale yellow in color and slightly granular in appearance, and if no eggs could be extruded from the vent under heavy pressure; ripening

Table 5. Frequency of Occurrence (in per cent) of Different Stages of Gonad Development by Age Group for 334 Northern Kingfish Taken by Ocean Seine During May and June, 1963–1964.

Sex	Stage of gonad development	May			June		
		Age group			Age group		
		I	II	III	I	II	III
Male	Unripe	22.3	3.1	..	20.0	..	..
	Ripening	13.2	40.6	20.0	20.0	15.4	..
	Running ripe	64.5	56.3	80.0	60.0	84.6	..
Female	Unripe	57.4	14.3	..	38.9	28.6	..
	Ripening	42.6	76.2	100.0	55.6	42.8	..
	Running ripe	..	9.5	..	5.6	28.6	..

if the ovaries were slightly enlarged or swollen, bright yellow in color and very granular in appearance, and if some eggs could be extruded from the vent under medium pressure; running ripe if the ovaries were greatly enlarged and swollen and deep golden yellow to nearly orange in color, and if the eggs were large and translucent and flowed freely from the vent under slight or no pressure. These observations are summarized in Table 5.

Welsh and Breder (1923) reported that the northern kingfish reaches maturity during the third or fourth summer of life, i.e., at the age of 2 or 3 years. Furthermore, they stated that males appear to mature earlier, i.e., at 2 years of age, than the females which they suggested do not spawn until they are 3 years old. The data presented in Table 5, however, seem to indicate that many fish as young as 1 year were sexually mature. Indeed, more than 50 per cent of all 1- and 2-year-old males examined were found to be running ripe, while a large percentage of the females from the same age groups were at or approaching spawning condition. All young-of-the-year kingfish examined during the present study were found to be immature, i.e., the sexes could not be determined by visual inspection.

DISCUSSION

Northern kingfish first appear in the inshore waters of Long Island in late April or early May and remain until late autumn at which time they vacate the area. The wintering grounds of the species are unknown,

but presumably they are offshore and to the south in deeper water. From year to year during the present study the first specimens were taken on April 29 in 1962, on May 6 in 1963, and on April 28 in 1964; the last specimens were taken on October 25 in 1962 and 1963, and on October 27 in 1964. Surface water temperatures and salinities ranged from 46° to 50° F. and 33.2 to 33.3 0/00, respectively, on the early capture dates, and from 55° to 60° F. and 31.6 to 32.2 0/00, respectively, on the late capture dates. Phillips (1914) reported taking his earliest specimen on May 4 at Corson's Inlet, New Jersey, while Latham (1917, 1920, 1923) listed dates between May 8 and 15 as the period of earliest capture at Orient, New York. Late capture dates have been given as October 11 at Corson's Inlet, New Jersey (Phillips, 1914), November 4 at Coney Island, New York (Wiegmann and Nichols, 1915), and December 8 at Orient, New York (Latham, 1917).

The spawning period has been rather well established. Some early authors noted the common occurrence of ripe fish during June at both Woods Hole, Massachusetts (Smith, 1898) and Narragansett Bay, Rhode Island (Tracy, 1910). Welsh and Breder (1923), based on investigations at Atlantic City, New Jersey, placed the spawning period at June through August, with a maximum in late June or early July, while Hildebrand and Cable (1934) suggested that spawning begins no later than April and continues through May and probably later at Beaufort, North Carolina. For Long Island, Perlmutter (1939) reported collecting eggs only during June but found postlarvae from June through July. Warfel and Merriman (1944) presented data collected in Connecticut waters that suggest spawning from June to August. The observations made during the present study, i.e., the condition of the gonads of adult specimens in May and June, the first appearance of many small juveniles in early July, and the size distributions of young fish during the summer, seem to indicate that spawning does reach a maximum during June in New York waters but continues to a lesser extent (during some years at least) through August and into September. Data collected by deSylva *et al.* (1962) in Delaware Bay suggest a similar lengthy protraction of the spawning season.

Welsh and Breder (1923) reported the incubation period of the eggs as from 46 to 50 hours at a temperature of 68° to 70° F. They also reported that the larvae are from 2 to 2.5 millimeters in length at hatching and that a few attain a size of 2.8 millimeters when 7 days old. Perlmutter (1939) described larval kingfish between the newly hatched and 10-millimeter sizes, and Hildebrand and Cable (1934) described larvae from 10 to 25 millimeters in length and larger, but the exact ages of these specimens were not reported. The smallest specimens captured during the present study were approximately 25 millimeters in length

and, it can reasonably be assumed, were probably no more than 1 month old at that size.

Earlier authors have suggested that the growth of the northern kingfish is exceedingly rapid during the first summer of life. Welsh and Breder (1923) reported that juveniles taken at Woods Hole, Massachusetts, may attain maximum lengths of 20 millimeters by July 1, 80 millimeters by August 1, and over 150 millimeters by September 1, while modal lengths for fish hatched in late June or early July were about 50 millimeters for August 1 and 100 millimeters for September 1. Moreover, the same authors reported a modal length of 40 millimeters, with a range of 25 to 90 millimeters, for juveniles taken in early August at Cape May, New Jersey, and a range of 90 to 140 millimeters for some additional examples taken from Chesapeake Bay in early September. They also suggested that the species reaches a modal length of about 120 millimeters by the first winter in New Jersey waters. Hildebrand and Schroeder (1928) collected what they believed to be young of the year in Chesapeake Bay ranging in size from 35 to 154 millimeters in late September and 50 to 185 millimeters in October. Hildebrand and Cable (1934) reported taking specimens 10 to 93 millimeters in length in late June, 20 to 116 millimeters in July, and 70 to 95 millimeters in August at Beaufort, North Carolina. The data collected during the present study suggest that the first summer's growth is even more rapid than that indicated by all these previous authors. Indeed, it would appear that some fish, probably those hatched in late May or early June, are capable of attaining by October a modal length of nearly 250 millimeters with a maximum length of 300 millimeters. It is possible, therefore, that the specimens between 8.5 and 11 inches in length collected in October by Hildebrand and Schroeder (1928), which they believed to be older than age 0, could have been early spawned young of the year.

It has also been reported that the species reaches a modal length of about 250 millimeters by the second winter and 350 millimeters by the third winter (Welsh and Breder, 1923). These estimates, based on an examination of the scales of a small series of New Jersey examples, seem somewhat conservative in view of the findings of the present study. The present data indicate that the northern kingfish (sexes combined) attains approximate average sizes of 260 millimeters by the second summer, 325 millimeters by the second winter, 335 millimeters by the third summer, 365 millimeters by the third winter, and 375 millimeters by the fourth summer. Furthermore, Welsh and Breder (1923) stated that growth falls off rapidly in the autumn and practically ceases during the winter. The present data seem to confirm this observation; differences between average summer size and that of the previous winter were very small, whereas differences between average summer size and that of the

succeeding winter were quite large. The major period of annual growth for the species is apparently from midsummer to late fall.

The population of northern kingfish in Long Island waters is generally comprised of either two or three age groups depending upon the season of the year. In spring and early summer 1- and 2-year-old fish are dominant, while from midsummer to late fall young of the year, 1-year-olds and 2-year-olds make up the bulk of the catch. Three-year-old fish are few in number during all seasons, and 4-year-olds are practically non-existent. The latter age group was the oldest collected during the present study.

Such a population age structure might, perhaps, partially explain past fluctuations in the size composition and abundance of the species as described by earlier authors. Bean (1903), for example, reported that adult kingfish were once common in Great South Bay but were rare there in 1884 and, although young were taken, only one was collected by him in 1898. However, the same author stated that large kingfish were not uncommon in Great South Bay in 1901 but that the young were unusually rare; only two specimens were captured. Similarly, Phillips (1914) noted at Corson's Inlet, New Jersey, that "the remarkable variation in numbers of this fish in different years is as noticeable here as at other points, the species occurring in great abundance for one or two years and then gradually decreasing from year to year until few are caught". Clearly, it is conceivable that the absence of any one or more age groups (0, I or II) from the over-all population could result in a severe reduction in numbers and cause a major change in the length composition of the catch. It seems reasonable to conclude, therefore, that the level of abundance and the size distribution of the northern kingfish population is highly dependent upon the success or failure of individual year classes. Moreover, because of the apparently short life-span and high mortality rate of the species, it is doubtful that the present prohibition against trafficking in kingfish less than 8 inches (203 millimeters) in length affords this fish any practical protection

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FACTORS AFFECTING GROWTH AND MATURITY IN A WALLEYE POPULATION[1]

John L. Forney Assistant Professor
Department of Conservation, Cornell University

ABSTRACT

The age distribution of a spawning population of walleyes in Oneida Lake was determined from samples collected between 1946 and 1963. The proportion of age VI and younger fish in the run increased during recent years. Examination of walleyes in late fall indicated a trend toward earlier maturity which was associated with more rapid growth of the 1959 and 1960 year classes. From 1 to 16 per cent of the adult females examined in late fall during the period 1959 to 1962 had failed to form eggs by October.

Lengths at each annulus were calculated for samples collected from the spawning run and during the growing season using a straight-line relationship with an intercept of 2.28 inches. Growth of individual year classes appeared independent of their numerical size from 1952 to 1959. Annual changes in growth increment were more closely correlated with yearly fluctuations in abundance of young yellow perch than with annual temperature indices or the biomass of walleyes from 1957 to 1962.

Rates of exploitation derived from angler tag returns were correlated with annual growth increments and suggested that vulnerability of walleyes to angling was high in years when food was scarce.

The walleye *(Stizostedion vitreum vitreum)* is the most important sport fish in Oneida Lake, New York. Grosslein (1961) estimated that annual fishing pressure averaged nearly one million man hours and that the annual walleye catch ranged from 40,000 to 463,000 fish in the period 1957 to 1959. The lake has an area of 50,000 acres with a maximum depth of 55 feet and a mean depth of approximately 25 feet. Limnological features of Oneida Lake and the early fishery were described by Adams and Hankinson (1928). Stone and Pasko (1946) reported on the growth of walleyes based on samples taken in 1944 and 1946. The present paper describes the age structure of the spawning population between 1946 and 1963 and analyzes fluctuations in growth rate and their relation to population density, abundance of forage fish and rate of angling exploitation.

Scale samples and measurements were collected for 15 years from walleyes trapnetted at the mouth of Scriba Creek during the spawning run. Most of the trap nets used had 125-foot leads and 25-foot wings of 3-inch stretch mesh. The car varied in size from 4 by 6 feet to 8 by 8 feet and was made of 2-inch stretch mesh. Growth data were also obtained from walleyes taken in experimental nylon gill nets of 1.5-,

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[1] A contribution of Federal Aid in Fish and Wildlife Restoration Project F-17-R. Data from 1946 to 1955 were collected by biologists of the New York State Conservation Department, including U.B. Stone, D.G.Pasko, A.C. Petty and J.P. Galligan. Personnel of the Oneida Fish Hatchery provided valuable assistance throughout the study. C.B. Taylor assisted in all phases of the field work and Mrs. A.A. Klock aided in preparing the manuscript. H.A. Regier reviewed and commented on the manuscript.

2.0-, 2.5-, 3.0-, 3.5- and 4.0-inch mesh set overnight at 15 locations each year from 1957 through 1963.

Total lengths of fish were measured to the nearest 0.1 inch, and scales were taken from an area below the lateral line just posterior to the end of the extended pectoral fin. Cellulose acetate impressions were made from scales and examined on a microprojector with a magnification of 31X.

AGE ASSESSMENT

The most significant criteria for recognition of annuli were abrupt changes in spacing of circuli on the anterior field and anastomosis of circuli on the lateral field. Annuli were usually well-defined through age IV, but age determination became progressively more difficult among older fish which, in years of exceptionally slow growth, occasionally failed to form an identifiable annulus.

Growth increments in 1956 were the lowest of those for the calendar years from 1948 through 1963. Samples of walleyes taken from July through October of 1956 indicated that 22 per cent of age IV+, 30 per cent of age V+, and 60 per cent of age VI+ and older fish had not formed an annulus by October (Table 1). Failure to form an annulus

Table 1. Percentage of Walleyes that Had Last Annulus Completed for Samples Caught in Gill Nets During July, September and October of 1956*

Month	Age group				
	II	III	IV	V	VI–IX
July	100 (19)	80 (10)	36 (102)	38 (12)	21 (32)
September	100 (29)	100 (11)	77 (89)	71 (9)	42 (24)
October	100 (49)	100 (11)	78 (95)	70 (6)	40 (32)

* Number of fish in parentheses.

was more prevalent among males than females, and occurred among age VI and older fish in 1953 and 1959 as well as in 1956. Assignment of ages in years when annulus formation was incomplete was facilitated by the presence of a number of year classes which exhibited distinctive growth patterns on the scales that could be easily recognized. Ages reported for walleyes hatched prior to 1948 may be in error since few collections were made and it was impossible to determine if annulus

TABLE 2. PERCENTAGE OF MALE AND FEMALE WALLEYES IN SAMPLES TRAPNETTED DURING SPAWNING RUNS IN SCRIBA CREEK FROM 1946 TO 1963

Year	Number of fish	Age group											
		III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV
Male													
1946	104	2.9	11.5	26.0	20.2	23.1	13.5	2.9	..	..	..	..	..
1948	212	1.4	12.3	18.9	18.9	17.9	17.0	9.4	33.0	0.9	..	..	..
1952	158	..	22.2	16.5	12.7	12.7	13.9	13.3	7.6	1.3	..	..	..
1953	200	..	9.5	51.5	16.5	5.5	6.5	6.5	3.0	1.0	..	..	..
1954	200	..	4.0	5.5	46.0	17.5	14.5	3.5	7.0	2.0	..	..	..
1955	32	..	9.4	6.3	6.3	50.0	15.6	3.1	9.4	..	..	..	..
1956	250	0.4	38.0	11.2	5.6	10.4	22.4	7.6	2.4	0.8	0.8	0.4	..
1957	250	0.8	1.6	55.6	11.2	4.8	6.8	13.6	2.0	2.0	1.2	..	0.4
1958	251	2.4	69.3	2.0	14.7	2.0	5.2	2.8	1.6	..	..	..	..
1959	228	0.9	6.1	75.4	0.9	10.1	2.6	1.3	1.3	0.9	..	0.4	..
1960	254	2.4	4.7	4.7	70.5	0.8	10.6	3.5	2.4	0.4	..	..	..
1961	274	0.4	54.4	5.5	12.0	20.8	0.7	5.1	0.7	0.4	..	..	..
1962	264	20.5	7.6	46.6	2.7	1.1	18.6	0.8	1.9	0.4	..	..	..
1963	334	11.1	29.9	7.8	32.9	2.7	1.2	12.0	0.9	1.5	..	..	..
Female													
1946	119	..	5.0	28.6	17.6	24.4	17.6	6.7	..	..	..	..	..
1951	61	..	6.6	21.3	11.5	14.8	16.4	19.7	9.8	..	..	..	..
1952	90	..	3.3	8.9	21.1	8.9	17.8	18.9	7.8	8.9	2.2	2.2	..
1953	174	..	..	9.8	19.5	14.9	11.5	20.1	16.1	3.4	4.0	0.6	..
1954	200	..	..	6.0	35.0	19.5	14.5	4.0	9.5	6.0	5.0	0.5	..
1955	69	..	2.9	5.8	18.8	37.7	18.8	13.0	1.4	1.4	..	..	..
1956	250	..	12.0	20.4	7.6	14.4	36.4	3.6	2.8	1.2	1.2	..	0.4
1957	251	..	1.2	26.7	10.0	7.2	11.2	21.1	10.4	4.0	5.2	3.2	..
1958	250	..	18.0	1.2	44.0	14.0	4.8	5.2	10.0	2.0	0.8	..	..
1959	325	..	4.0	76.9	0.6	13.2	1.8	1.5	1.2	0.6	..	..	..
1960	260	..	0.4	8.8	57.7	1.2	16.2	3.8	4.6	4.2	1.9	1.2	..
1961	264	..	9.1	4.5	6.1	58.3	1.5	16.3	2.7	1.1	..	0.4	..
1962	260	..	1.2	56.2	4.6	3.1	24.6	2.3	7.3	0.8	..	..	..
1963	434	0.7	24.9	7.1	48.8	2.8	2.1	11.3	1.4	0.9	..	..	..

formation occurred regularly. However, validity of the age assessments for recent year classes is indicated by the consistent variation in abundance between year classes collected in successive years (Table 2) and by the agreement between year classes as to good or poor growth in certain calendar years (see Table 11).

AGE STRUCTURE OF THE SPAWNING POPULATION

Samples of walleyes trapnetted at Scriba Creek were processed for growth data after fish cultural operations in 1946 and 1948 and each spring from 1951 to 1963. The 1948 sample consisted entirely of males, and the 1951 sample included only females. Comparison of the age dis-

tribution of age V and older walleyes taken in the spawning run with the age distribution in samples taken at other times in Oneida Lake suggest that the spawning run sample accurately portrayed the age structure of the mature walleye population (Forney, 1961).

The spawning run was composed primarily of age groups IV to VIII among males and age groups V to IX among females (Table 2). Strong year classes produced in 1948, 1952, 1954 and 1957 were dominant in the spawning run catch for several successive years after reaching maturity. Most females did not mature until age V, and the proportion of age IV females in the catch was generally low. Age III males comprised a minor part of the catch except in 1962 and 1963 when they represented 20.5 and 11.1 per cent, respectively. From Table 2 it appears that an increasing proportion of the spawning run has consisted of younger age groups in recent years, but fluctuations in year class strength make evaluation of this change difficult.

In the period 1946 to 1952, 62 per cent of the males and 38 per cent of the females in the spawning run were age VI or younger. Age distribution for the period 1953 to 1957 was similar with 50 per cent of the males and 36 per cent of the females being in this age range. But during the years 1958 to 1963 these proportions increased to 81 per cent and 59 per cent, respectively, because fish in age groups III to VI were more numerous. Earlier maturity of the 1959 and 1960 year classes was partly responsible for the higer proportion of young fish in the spawning run in recent years.

Table 3. Percentage of Males and Females of Different Ages That Were Mature or Maturing in the Fall for Samples Collected by Electrofishing and Trapnetting from 1959 to 1962*

Year	Sex and age					
	Male			Female		
	I+	II+	III+	II+	III+	IV+
1959.....	0 (20)	0 (23)	100 (4)	0 (21)	0 (3)	50 (6)
1960.....	0 (7)	33 (3)	93 (44)	0 (16)	32 (76)	75 (8)
1961.....	0 (6)	80 (10)	100 (6)	4 (26)	0 (6)	87 (45)
1962.....	9 (11)	56 (64)	100 (77)	1 (89)	78 (83)	100 (7)

* Number of fish in parentheses.

Samples of walleyes were collected during October in 1959, 1960, 1961 and 1962, and the gonads were examined to estimate the percentage of mature fish in the different age groups (Table 3). In 1959 all age II+ males examined in October were immature, but in 1961 and 1962 over 50 per cent had well developed testes and would have spawned the following spring as age III fish. Females showed a similar trend toward earlier maturity during the period of 1959 to 1962. Earlier maturity was associated with above-average growth rates of the 1959 and 1960 year classes. Females of the 1959 year class maturing in the fall of 1962 averaged 15.4 inches in total length compared with 14.3 inches for females of the 1957 year class maturing in the fall of 1960. The importance of size in determining maturity is indicated by the fact that mature males and females averaged consistently larger than immature fish of the same year class (Table 4).

TABLE 4. TOTAL LENGTHS OF MATURE AND IMMATURE WALLEYES TAKEN BY ELECTROFISHING DURING OCTOBER OF 1960 AND 1962

Year	Sex	Age group	Immature			Mature		
			Number	Mean length	Range	Number	Mean length	Range
1960....	Male	I+	7	11.3	10.9–12.3	..	..	..
		II+	2	12.5	12.1–12.9	1	13.3	..
		III+	4	12.9	12.0–13.4	40	13.5	12.4–15.5
	Female	II+	16	13.0	11.7–13.9	..	..	..
		III+	51	13.9	12.2–15.7	24	14.3	13.2–15.6
		IV+	2	14.3	13.3–15.2	6	16.0	14.2–18.7
1962....	Male	I+	9	10.4	9.8–11.2	1	10.7	..
		II+	28	12.6	11.8–13.4	36	12.8	12.0–13.6
		III+	..	..	..	77	14.4	12.8–16.0
	Female	II+	88	13.2	11.4–15.5	1	15.0	..
		III+	18	14.2	12.5–17.2	65	15.4	13.5–17.3
		IV+	..	..	..	7	15.8	14.6–17.1

Deason (1933) and Carlander (1945) reported for other waters that some older female walleyes may be sterile or fail to spawn annually. Female walleyes collected in Oneida Lake in October could be separated into three groups by examining the ovaries, i.e., immature fish, females with well-developed eggs in the ovaries, and "non-ripening" females with ovaries typical of spent females as described by Eschmeyer (1950). The proportion of "non-ripening" females was highest in the fall of 1959 when it constituted 16 per cent of the adult females examined, but in 1960, 1961 and 1962 it was less than 5 per cent (Table 5). Growth

Table 5. Proportion of "Non-ripening" Adult Female Walleyes in Samples Taken During October and November from 1959 to 1962

Year	Number examined	Percentage "non-ripening"
1959	107	15.9
1960	99	4.0
1961	149	1.3
1962	141	3.5

Table 6. Length-frequency Distribution of Male and Female Walleyes Taken During Spawning Runs in Scriba Creek from 1951 to 1958

Size (inches)	Male		Female	
	Number	Per cent	Number	Per cent
11.5–11.9	7	0.2	..	..
12.0–12.4	22	0.8	..	..
12.5–12.9	45	1.6	1	<0.1
13.0–13.4	112	4.0	2	0.1
13.5–13.9	212	7.5	8	0.4
14.0–14.4	355	12.5	35	1.8
14.5–14.9	443	15.6	103	5.3
15.0–15.4	375	13.2	128	6.6
15.5–15.9	353	12.5	169	8.7
16.0–16.4	296	10.5	171	8.8
16.5–16.9	246	8.7	165	8.5
17.0–17.4	161	5.7	171	8.8
17.5–17.9	86	3.0	164	8.5
18.0–18.4	60	2.1	154	8.0
18.5–18.9	31	1.1	130	6.7
19.0–19.4	14	0.5	125	6.4
19.5–19.9	6	0.2	97	5.0
20.0–20.4	2	0.1	85	4.4
20.5–20.9	3	0.1	44	2.3
21.0–21.4	0	0.0	38	2.0
21.5–21.9	1	<0.1	35	1.8
22.0–22.4	..	..	38	2.0
22.5–22.9	..	..	28	1.4
23.0–23.4	..	..	17	0.9
23.5–23.9	..	..	8	0.4
24.0–24.4	..	..	10	0.5
24.5–24.9	..	..	2	0.1
25.0–25.4	..	..	3	0.2
25.5–25.9	..	..	1	<0.1
26.0–26.4	..	..	2	0.1
26.5–26.9	..	..	0	0.0
27.0–27.4	..	..	1	<0.1
Total	2,830	100.0	1,935	100.0

TABLE 7. MEAN TOTAL LENGTH IN INCHES FOR WALLEYES OF DIFFERENT AGES TAKEN DURING SPAWNING RUNS IN SCRIBA CREEK FROM 1946 TO 1958*

Sex	Age group											
	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV
Male....	12.8 (19)	13.9 (379)	14.5 (385)	15.1 (291)	15.8 (195)	16.5 (207)	17.1 (130)	17.3 (57)	18.0 (17)	19.1 (5)	18.2 (1)	19.1 (1)
Female..	..	15.1 (93)	16.0 (209)	16.9 (318)	17.9 (226)	18.6 (240)	19.4 (164)	20.7 (121)	21.8 (45)	22.5 (37)	22.9 (12)	21.4 (1)

* Number of fish in parentheses.

increments were exceptionally low in 1959 which suggests that the high proportion of "non-ripening" females in the fall of 1959 was caused by a limited food supply during the growing season.

Male walleyes 14 to 16 inches long and females 15 to 19 inches long usually predominated in the spawning run (Table 6). The difference in size was caused by the earlier maturity of males and a pronounced divergence in growth rate of the two sexes. Mean observed length of age V males in the spawning runs from 1946 to 1958 was 14.5 inches compared with 16.0 inches for females (Table 7), and at age X the difference in mean length exceeded 3 inches.

BODY-SCALE RELATIONSHIP

Relationship between scale radius and body length was determined from measurements of 1,200 scales from fish 5 to 20 inches in total length. Walleyes from eight year classes taken by gillnetting, trapnetting and trawling were represented in the length-scale regression. Individual measurements were divided into suitable length-class intervals, and a regression table of total length on magnified scale image was made by a method described by Goulden (1952). A statistical test of deviations from linearity indicated nonsignificance at the 5 per cent level. The intercept of the linear relationship was calculated by least squares to be 2.28 inches. Measurements of projected scale images were recorded on paper tabs and the length at each annulus was estimated by using a nomograph based on direct proportion corrected for the intercept (Carlander and Smith, 1944).

DESCRIPTION OF GROWTH

Calculated lengths were determined from fish of ages I to VII taken in gill nets and from males of ages IV to VII and females of ages V to VII taken during the spawning run. Older fish were excluded because of difficulties in judging the age of some year classes. Age III

males and age IV females in the spawning run were not used since these groups represented more rapidly growing individuals of the year class.

Growth of year classes hatched prior to 1954 was based on back-calculations on scales taken from walleyes in the Scriba Creek spawning run. Beginning in 1959 calculated lengths were determined primarily from scales of specimens caught in experimental gill nets. Mean calculated lengths for the 1954 year class, based on samples collected in gill nets in the summer of 1959 and on samples from the same year class taken in the 1960 Scriba Creek spawning run, are compared in Table 8.

Table 8. Calculated Total Lengths (in inches at each annulus) of Walleye of the 1954 Year Class for Samples Taken in Gill Nets in Oneida Lake During 1959 and from the Scriba Creek Spawning Run in April 1960

Sex	Source	Number	Annulus				
			1	2	3	4	5
Male...	Scriba Creek	179	5.40	9.36	10.43	13.00	14.26
	Oneida Lake	75	5.52	9.26	10.63	13.26	14.30
Female.	Scriba Creek	150	5.63	9.69	10.79	13.95	15.58
	Oneida Lake	85	5.73	9.77	11.05	13.97	15.29

Differences in mean lengths calculated from the two samples did not exceed 0.3 inch at any annulus. Thus, gillnet and spawning-run samples provided similar estimates of growth.

Growth of Individual Year Classes

Individual year classes exhibited considerable variation in growth, but there was no evidence of a linear trend in growth rate over a 20-year period (Table 9). Two of the fastest growing year classes, judged by lengths attained by the end of the third year, were those of 1959 and 1960. The rapid growth of these recent classes may portend a trend toward more rapid growth in this population. However, there was little evidence among earlier year classes that the growth rate during the first three years of life was closely correlated with growth in later years. Mean lengths for the 1945 to 1957 year classes at age III showed a relatively weak correlation of 0.42 for females and 0.38 for males with mean lengths for the same year classes at age VI. It was also apparent that differences in mean length between year classes tended to decrease as age increased. For males in the 1945 to 1957 year classes mean lengths at the third annulus ranged from 10.5 to 12.5 inches, but at the

TABLE 9. MEAN CALCULATED TOTAL LENGTHS (IN INCHES AT EACH ANNULUS) OF MALE AND FEMALE WALLEYES OF THE 1939 TO 1962 YEAR CLASSES

Year class	Number of fish	Annulus						
		1	2	3	4	5	6	7
Male								
1939–1944	231	5.8*	9.2	11.8	13.5	14.3	14.9	15.6
1945	23	5.6	8.9	11.8	13.4	14.5	15.5	16.1
1946	33	5.7	8.7	11.8	14.0	14.8	15.4	16.3
1947	87	5.7	9.3	11.9	13.2	14.1	15.4	15.8
1948	250	5.6	8.7	10.8	12.5	14.6	14.9	16.0
1949	59	6.0	8.2	11.0	13.8	13.9	15.2	16.1
1950	37	5.3	8.7	12.0	12.7	14.5	15.7	15.8
1951	63	5.9	9.7	11.1	13.9	15.2	15.4	16.3
1952	269	6.6	8.2	11.7	14.2	14.3	15.7	..
1953	12	5.8	9.4	12.5	13.0	14.3	14.9	15.3
1954	479	5.5	9.5	10.5	13.4	14.3	14.8	15.6
1955	42	6.7	8.9	11.8	13.4	14.1	15.3	16.0
1956	38	5.8	9.5	11.4	12.3	14.1	15.9	16.3
1957	180	6.7	9.2	10.9	13.3	14.8	15.5	..
1958	38	5.9	8.9	11.8	13.8	14.8	..	..
1959	107	7.0	10.4	12.8	14.4	..	..	..
1960	67	6.8	9.6	12.6	..	..	..	..
1961	22	7.0	10.1	..	..	..	..	..
1962	7	6.3	..	..	..	..	..	..
Unweighted mean	2,044	6.1	9.2	11.6	13.4	14.4	15.3	15.9
Female								
1939–1944	99	6.1*	9.5	12.2	13.9	15.2	16.2	17.1
1945	15	5.7	9.0	11.6	13.7	15.3	15.9	17.0
1946	58	6.2	8.9	12.5	14.7	15.7	16.8	17.9
1947	86	6.0	9.9	12.8	14.1	15.4	17.0	17.2
1948	116	5.9	9.3	11.0	13.2	15.6	15.9	17.6
1949	61	6.3	8.4	11.4	14.5	15.2	17.3	18.9
1950	42	5.7	9.2	12.7	13.6	16.2	18.2	18.6
1951	111	5.8	9.8	11.3	14.6	17.0	17.3	18.6
1952	207	6.9	8.6	12.4	15.4	15.8	17.5	..
1953	9	6.2	10.6	13.7	14.4	15.7	16.9	17.3
1954	322	5.8	9.9	11.1	14.1	15.5	16.6	17.1
1955	39	7.0	8.8	12.2	14.1	15.2	15.9	17.6
1956	25	6.5	9.7	11.8	13.1	14.6	16.3	16.7
1957	291	6.7	9.3	11.3	13.8	15.4	16.6	..
1958	36	6.0	9.0	12.2	14.1	15.2	..	..
1959	99	7.0	10.5	13.0	14.7	..	..	..
1960	70	7.1	10.1	12.9	..	..	..	..
1961	16	6.7	10.1	..	..	..	..	..
1962	10	6.3	..	..	..	..	..	..
Unweighted mean	1,712	6.3	9.5	12.1	14.1	15.5	16.7	17.6

* Unweighted mean of 1939 to 1944 year classes.

sixth annulus the range was from 14.8 to 15.9 inches. Annual differences in rate of growth strongly influenced the length attained at the second

or third annulus but, over a longer period, years of above- and below-average growth tended to compensate. The smaller range in mean lengths in later years of life may also have reflected growth compensation among individual fish in different year classes.

Growth of the 1952 to 1959 year classes appeared to be independent of numerical abundance of the individual year class. Abundance of each year class at age IV was determined from annual population estimates made by age groups from 1957 to 1963 (Forney, 1962). The 1954 year class was from 1.8 to over 100 times as abundant as other year classes at age IV, but its growth, based on calculated length at the fourth

Table 10. Mean Calculated Total Lengths at Age IV and Estimated Numbers at Age IV for 1952 and 1959 Year Classes

Year class	Mean length			Estimated number
	Male	Female	Average	
1952	14.2	15.4	14.8	321,000*
1953	13.0	14.4	13.7	6,600
1954	13.4	14.1	13.8	782,800
1955	13.4	14.1	13.8	55,600
1956	12.3	13.1	12.7	37,200
1957	13.3	13.8	13.6	430,900
1958	13.8	14.1	14.0	65,200
1959	14.4	14.7	14.6	290,200

* Computed by dividing the estimated number of age V walleyes in 1957 by total mortality rate in 1956 computed from marked fish.

annulus, was about average (Table 10). In Oneida Lake competition within a year class did not appear to be markedly greater than competition between year classes. But in Clear Lake (Iowa) Carlander and Whitney (1961) observed a relation between slow growth and abundant year classes.

Growth in Different Calendar Years

Pronounced yearly fluctuations in growth increment occurred between 1948 and 1962 (Table 11). Growth increments in 1953, 1956 and 1959 were much below average, but growth in 1952, 1954 and 1957 was above average for the period. In years of exceptionally rapid or slow growth all age groups except young of the year showed the same trends

TABLE 11. MEAN ANNUAL INCREMENT IN LENGTH (IN INCHES) AND GROWTH INDEX FOR MALE AND FEMALE WALLEYES IN DIFFERENT YEARS OF LIFE DURING VARIOUS CALENDAR YEARS

Calendar year	Year of life							Growth index
	1	2	3	4	5	6	7	
Male								
1948	55.5	3.58	3.17	1.80	..	..	..	114.9
1949	6.04	3.12	2.67	2.13	1.15	..	..	105.2
1950	5.29	2.13	1.80	1.23	0.83	0.93	..	72.3
1951	5.88	3.40	2.79	1.99	0.90	0.56	0.66	92.5
1952	6.60	3.83	3.32	2.96	2.28	1.41	0.88	143.1
1953	5.77	1.60	1.36	0.67	0.14	0.30	0.22	41.8
1954	5.53	3.68	3.46	2.80	2.10	1.42	1.40	144.8
1955	6.70	3.99	3.02	2.52	1.39	1.22	0.89	127.0
1956	5.85	2.24	1.00	0.56	0.39	0.24	0.17	44.8
1957	6.73	3.61	2.90	2.84	1.48	1.61	1.14	132.3
1958	5.87	2.46	1.90	1.70	1.16	1.10	..	86.8
1959	6.89	3.02	1.76	1.16	0.67	0.52	0.30	69.8
1960	6.75	3.52	3.04	2.28	1.58	1.03	0.72	118.6
1961	6.97	2.88	2.39	1.80	1.34	1.47	0.72	103.3
1962	6.34	2.98	2.94	1.56	1.12	0.76	0.57	96.8
Unweighted mean	6.18	3.07	2.50	1.87	1.18	0.97	0.67	
Female								
1948	5.87	3.92	3.59	2.11	..	..	..	120.8
1949	6.34	3.44	2.98	2.38	1.40	..	..	107.8
1950	5.67	2.05	1.73	1.25	0.85	0.77	..	62.6
1951	5.80	3.52	3.02	2.16	1.30	0.86	0.52	98.8
1952	6.89	4.05	3.52	3.12	2.43	1.60	1.02	136.6
1953	6.19	1.67	1.49	0.88	0.65	0.30	0.27	45.6
1954	5.77	4.42	3.80	3.27	2.58	2.10	1.85	156.4
1955	6.94	4.11	3.11	3.08	2.42	2.06	1.79	143.8
1956	6.49	1.79	1.20	0.71	0.42	0.39	0.20	40.9
1957	6.71	3.17	3.48	3.04	1.93	1.93	1.26	128.6
1958	6.04	2.56	2.14	1.88	1.27	1.00	..	83.2
1959	7.00	3.01	2.00	1.20	1.06	0.76	0.43	73.4
1960	7.09	3.49	3.14	2.41	1.78	1.13	0.82	110.8
1961	6.73	3.03	2.53	1.96	1.67	1.43	0.80	99.1
1962	6.34	3.40	2.76	1.71	1.26	0.91	0.80	94.1
Unweighted mean	6.29	3.18	2.70	2.08	1.50	1.17	0.89	

in growth. In other years trends were less consistent, some increments being above and some below the average. Failure of all age groups to follow the same trends probably reflected both sampling variation and actual differences in growth conditions for fish of different sizes.

Growth indices for each calendar year were derived by dividing the sum of increments for the second to seventh years of life by the sum of

the corresponding unweighted means using the method described by Hile (1941). First-year growth increments were not included in the index because growth of young was not correlated with growth of older fish in the same year (rank correlation= —0.08). Smith and Pycha (1960) also observed that growth of young and that of older walleyes did not follow the same trends, and they concluded that growth of first-year fish in the Red Lakes (Minn.) was probably determined by different factors than that of older fish.

The most rapid growth of age I and older walleyes occurred in 1954 and the slowest growth in 1956, based on the average growth index for both sexes. Growth indices did not show any consistent trend toward faster or slower growth during the period of study. The average growth index was not correlated with mean May-September air temperatures[2] (rank correlation=0.04), nor did any other combination of monthly summer air temperature summations show a significant correlation with growth.

Changes in annual growth increment of walleyes since 1959 appear to have been related to fluctuations in density of young yellow perch. Young-of-the-year yellow perch were the most important forage fish in Oneida Lake, constituting from 50 to over 90 per cent of the summer food of walleyes each year. Beginning in 1959, between 48 and 96 hauls with an 18-foot otter trawl were made each year at selected locations to estimate the abundance of forage fish. The average catch per haul of young yellow perch from August through September was 57 in 1959, 814 in 1960, 516 in 1961, and 531 in 1962. Walleye growth increments during this period were lowest in 1959 when yellow perch were scarce and highest in 1960 when yellow perch appeared most abundant. Although the density of young yellow perch in earlier years was not measured, examination of scales of perch taken in gill nets from 1956 to 1959 indicated the 1954 and 1957 year classes were exceptionally strong (Pease, 1961) suggesting that young perch were abundant in these years. In both 1954 and 1957 growth of walleyes was above average.

Changes in walleye population density from 1957 to 1962 and mean growth increments for age groups III to V are illustrated in Figure 1. The number of walleyes in April of each year was estimated by mark and recapture, and the biomass of each year class was calculated from a between-ages length-weight regression (Forney, 1963). Biomass on July 1 and November 1 was approximated from within-season growth and mortality rates.

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[2] Recorded at U.S. Weather Bureau Station at Hancock Field located 9 miles south of Oneida Lake.

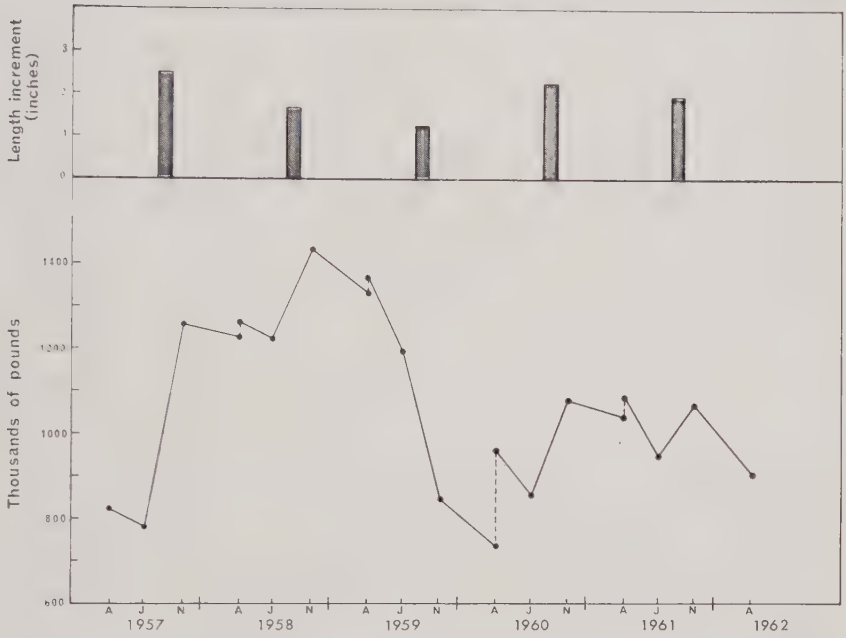

Figure 1. Standing crop of age III and older walleyes on April 1, July 1 and November 1 from 1957 to 1962 and mean annual length increments for age groups III to V during the corresponding growing seasons.

Differences in biomass at the beginning and end of a growing season were of such magnitude that it was difficult to evaluate the effect of population density on growth. Although mean biomass during the growing season was about the same each year except in 1958, annual length increments were variable. The largest length increments occurred in 1957 and 1960 when biomass at the beginning of the growing season (July 1) was low, and the increments were smallest in 1958 and 1959 when the biomass in July was high.

The predator-prey relationship between walleyes and young yellow perch in Oneida Lake has not been studied, but it is possible that differences in the standing crop of walleyes at the beginning of the growing season could affect growth. A high population of walleyes at the beginning of the growing season would be expected to remove yellow perch at a younger age than would a low population. Intensive predation may remove yellow perch at too early an age or size to permit an optimum yield of forage. Whether the size of the walleye population influences seasonal distribution of yellow perch mortality is not known, but it would seem to warrant investigation

Relation between Growth and Angling Mortality

Between 550 and 1,500 adult walleyes were jaw tagged each spring from 1952 to 1962. The proportion reported caught by anglers during the following fishing season (May 1 to March 1) provided an annual index of exploitation. Although rates of exploitation are governed by both fishing pressure and vulnerability of fish to angling, changes in vulnerability of walleyes appears to have been of primary importance in determining the annual rate of exploitation in Oneida Lake. This is suggested by the fact that annual fishing pressure during the years 1957 to 1959 varied 30 per cent, while rates of exploitation in these years varied 400 per cent (Grosslein, 1961).

Rates of exploitation were highest in 1953, 1956 and 1959, and in these years mean growth increments for walleyes in age groups IV to VI were the lowest of those for the 10-year period (Figure 2). Similarity in pattern of growth fluctuations and rates of exploitation strongly suggests that walleyes were more vulnerable to angling in years when growth conditions were unfavorable. Changes in vulnerability probably reflected fluctuations in the abundance of young yellow perch which may have some influence on growth rates as suggested under the preceding topic. Changes in vulnerability of walleyes to angling in response to changes in yellow perch abundance have been observed in other lakes (Moyle, 1949; Carlander, 1958).

DISCUSSION

Major changes in abundance of several species of fish have occurred in Oneida Lake during the period covered by this study. The lake emerald shiner, which was frequently observed in the stomachs of walleyes examined in 1941 (Raney and Lachner, 1942) and in 1952 (Galligan, 1960), has been very scarce since 1956. Gizzard shad and white perch entered the lake in the early 1950's. Although the gizzard shad disappeared after producing one or two strong year classes, white perch became established and they are now numerically the third most important species taken in experimental gill nets. Despite changes in species composition of the population and probable changes in fishing pressure, walleye growth rate has exhibited long-term stability although extreme annual fluctuations have occurred.

Absence of a linear trend in growth rate during the past two decades suggests that intraspecific competition did not change greatly during the period. Although many ecological mechanisms may act to maintain a stable relation between a predator and its food supply, the most obvious one for walleyes in Oneida Lake is the relation between growth and vulnerability to angling. High vulnerability of walleyes to angling in years of slow growth leads to a reduction in population

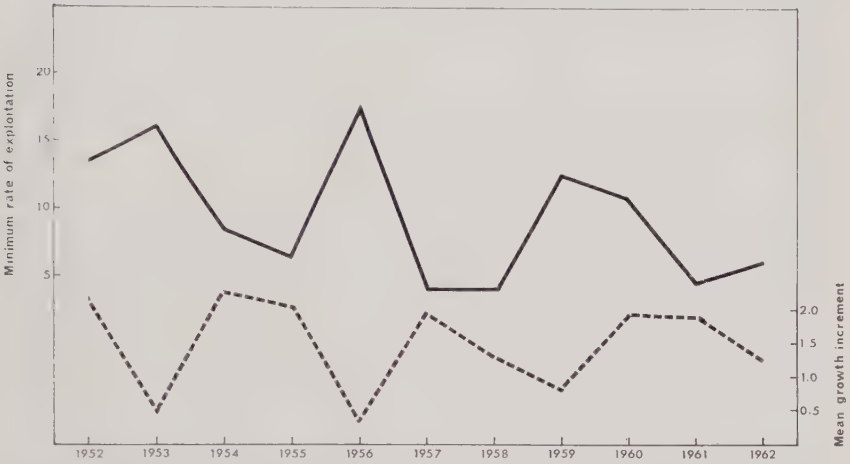

Figure 2. Mean growth increments (in inches) for ages IV to VI walleyes and minimum rates of exploitation based on tagged fish (percentage reported caught by anglers) for years 1952 to 1962.

density. Reduced competition in the following year should result in more rapid growth. A response to reduced competition is suggested by rapid growth in 1954, 1957 and 1960 following years in which rates of exploitation were relatively high (Figure 2). It should be noted that the rates of exploitation shown in Figure 2 were based on voluntary tag returns. Grosslein (1961) concluded that exploitation rates derived from tag returns were about one-third the true values for Oneida Lake.

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EVALUATION OF PARTIAL FIN CLIPS FOR MARKING LARGEMOUTH BASS, WALLEYES AND RAINBOW TROUT[1]

Alfred W. Eipper Leader
New York Cooperative Fishery Unit, Cornell University
John L. Forney Assistant Professor
Department of Conservation, Cornell University

ABSTRACT

Removing the distal half to two-thirds of the pectoral or ventral fins of 12-inch and larger walleyes, and the pectoral fins of 6- to 7-inch largemouth bass, produced a mark that was permanently and uniformly recognizable in the regenerated fin by a thickening and bending of rays along the excision line. Partial clips did not produce an easily recognizable mark on the ventral fins of these bass or on the pectoral, ventral, dorsal, or anal fins of 5-inch rainbow trout. It seems likely that the conspicuousness of the mark produced by partial clipping varies with the relative size of the fish when marked. As an adjunct to complete fin removal, partial clipping increases the number of groups of fish that can be distinctively marked at one time. Adverse effects of fin mutilation on survival and behavior are probably minimized because initial injury is less severe and partially clipped fins usually regenerate rapidly. Partial clipping is a fast marking procedure that requires almost no training and no special equipment other than a pair of diagonal wire-cutting pliers.

Stuart (1958) reported that when the distal half or two-thirds of a pectoral or pelvic (ventral) fin of a brown trout is removed, the fin regenerates to nearly its original length within a year, but remains recognizable throughout the life of the fish. Stuart found that the fin is always characteristically deformed and that usually a thickened ridge, marking the line of excision, is evident. Between 1959 and 1963, the authors used partial fin clips to mark largemouth bass (*Micropterus salmoides*), walleyes (*Stizostedion vitreum*) and rainbow trout (*Salmo gairdneri*).

In this study, partial fin clips were made by cutting across the fin at approximately right angles to the fin rays. When pectoral or ventral fins were clipped the distal half to two-thirds was removed. Clips were made using either surgical bone-cutting forceps or ordinary diagonal, wire-cutting pliers.

LARGEMOUTH BASS

Fifty largemouth bass averaging 6.9 inches long were each marked by removing half of the left pectoral and right ventral fins, after which they were stocked in a 0.2-acre pond in November 1959. One year later the pond was drained and the 42 surviving bass, averaging 11.3 inches long, were examined. Form and appearance of the regenerated fins differed little between individual fish. Pectorals and ventrals had regenerated to almost normal length (Figure 1).

[1] A contribution of Federal Aid in Fish and Wildlife Restoration Project F-15-R. A suggestion from Dr. Henry A. Regier prompted these studies. Mr. John Church devoted much time to developing suitable techniques for photographing regenerated fins and using polarized light to reveal partial clips.

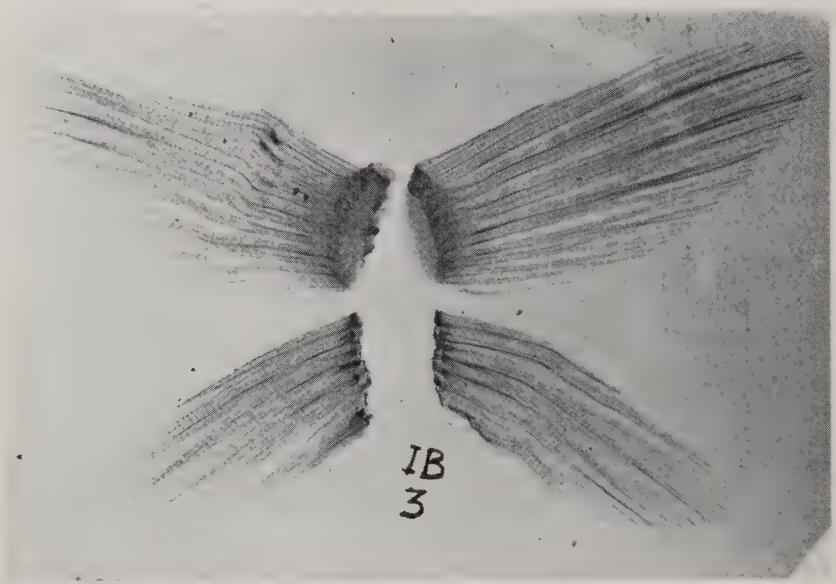

Figure 1. Pectoral and ventral fins of an 11-inch largemouth bass, one year after removing the distal halves of the left pectoral and right ventral fins.

All pectorals that had been partially clipped were easily recognized by the sharp, uniform bending and thickening of the fin rays along the excision line. Partially clipped ventral fins showed noticeable bending, but the deformity was not sufficiently pronounced to make this a reliably recognizable mark for large-scale field use. Possibly partial ventral clips would be more recognizable if made on larger bass.

WALLEYES

Ten walleyes 14 to 16 inches long were given half-pectoral clips and planted in a 0.2-acre pond in April 1961. Shortly afterward some 400 alewives were added as forage. When this pond was drained six months later, all 10 of the walleyes, but only 12 alewives, had survived. The partially clipped pectorals had regenerated to nearly normal length, but marks were readily identified by the bending and thickening of fin rays along the excision line. Deformities were most pronounced when the fin had been cut at right angles to the fin rays and when more than half of the fin had been removed. These findings agree with those of Stuart (1958).

At Oneida Lake (N.Y.) several thousand adult walleyes (over 12 inches long) netted in April from year to year were identified by removing half the right ventral fin of those marked in 1960, half the left ventral of those marked in 1961 and half the right pectoral of those

marked in 1962. Samples were subsequently collected in summer and fall of each year by electrofishing, trawling and gillnetting to estimate the ratio of marked to unmarked fish. All marked walleyes, as well as unmarked fish taken during sampling, were aged. This made it possible to subdivide the catch into year classes (or age intervals) and to eliminate the effect of subsequent recruitment of unmarked individuals into that segment of the population available to the sampling gear when marking was done. Using these data, the proportions of marked walleyes in the total catch of walleyes of comparable year classes collected in successive years were determined (Table 1). The proportion of half-right-ventral

Table 1. Numbers and Percentages of Fin-clipped Walleyes Taken in Oneida Lake During Summer and Fall from 1960 to 1963

Year	Total catch	Clipped fish	
		Number	Per cent
Marked and released in April 1960 (half right ventral fin clipped)*			
1960	3,582	92	2.57
1961	2,285	58	2.54
1962	1,214	27	2.22
1963	1,087	25	2.30
Marked and released in April 1961 (half left ventral fin clipped)§			
1961	5,090	152	2.99
1962	3,384	94	2.78
1963	2,595	75	2.89
Marked and released in April 1962 (half right pectoral fin clipped)†			
1962	3,756	138	3.67
1963	2,883	91	3.16

* 1956 and earlier year classes.
§ 1957 and earlier year classes.
† 1958 and earlier year classes.

fin clips in samples of the 1957 and earlier year classes and that of half-left-ventral fin clips among fish of the 1958 and earlier year classes did not decrease appreciably in successive annual samples. The number of half-pectoral fin clips observed in the 1963 sample was proportionally lower than that in the 1962 catch, but the decrease was within the limits of expected sampling error (chi-square test of homogeneity = 1.24, 1 d.f.). This indicates that these partial fin clips remained recognizable marks throughout the experiment.

As shown in Figure 2, half-ventral and half-pectoral clips on these walleyes (all age III or older) were distinctive. Often the regenerated portion of the fin was bent very sharply, with the rays splayed out. Al-

Figure 2. Pectoral fins of one 4-year-old walleye, and ventrals of another, one year after removing distal halves of right pectoral and left ventral fins.

though all marked fish were readily identifiable, these partial fin clips showed more variability between individual fish than did those on fish in the pond experiments. This variability may have been related to the variability in age, and hence growth rate, of the walleyes clipped at Oneida Lake.

Other adult walleyes from Oneida Lake were marked by clipping the following fins close to (but not flush with) the base: (1) the anterior four or five rays of the spinous dorsal, (2) the anterior half of the anal, (3) the posterior half of anal, and (4) the entire anal. Three years later the dorsal spines showed virtually no regeneration. Regeneration of

anal fins varied from none at all to a small amount accompanied by extreme deformity of the regenerated stubs. The partial anal clips often gave rise to formation of a membrane (but no rays) extending from the clipped end of the fin to the distal end of the first unclipped ray. The utility of anterior-dorsal and rear-anal clips is limited by the fact that usually the fin must be raised in order to detect these clips under field conditions.

RAINBOW TROUT

In November 1961, various partial fin clips were tested on small lots of 5 to 20 age 0+ rainbow trout that averaged 5.0 inches long. The fish were retained in hatchery troughs and observed periodically. A final

Figure 3. Ventral fins of a 1-year-old, 8-inch rainbow trout, 5½ months after half of left ventral (viewer's right) was excised and the cut edge treated with a 50 per cent solution of Sudan Black B in ethyl alcohol.

examination was made 5½ months after marking, when the fish had reached an average length of 8.2 inches. At this time the partially clipped fins had regained nearly their normal length. Pectoral, dorsal, and anal clips were detectable, but not obvious. Possibly the dorsal and anal clips had been made too close to the base. Recognition of caudal clips (dorsal or ventral 'corner') ranged from difficult to almost impossible, in contrast to Stuart's results with brown trout. Ventral clips showed a uniform, characteristic deformity (slight inward bend at point of excision) and were more recognizable than other partial clips used on rainbows, but they were not considered conspicuous enough for field experiments involving quick sorting of large numbers of marked and unmarked individuals.

Another technique tested with the small rainbow trout was partially clipping a fin and then daubing the cut end with a 50 per cent solution of Alizarin Red or Sudan Black. With caudal clips, both colors had virtually disappeared after 4 months. Dorsal, anal, and adipose clips treated with Sudan Black retained the black coloration at the excision site for the duration of the experiment, but after 5 months the naturally abundant black pigmentation of this species had effectively camouflaged the dye marks. A 20 per cent solution of Trypan Blue was ineffective in dying the stubs of partially clipped pectoral, ventral, and adiose fins. The combination of dye and partial cliping was somewhat more effective on pectoral clips, and much more effective on ventral clips. Five and one-half months after treatment, red was still faintly detectable in some of the pectoral rays and most of the ventral rays, but it showed a tendency to diffuse back toward the body. In the same time interval Sudan Black did not exhibit much diffusion and appeared as a faintly to moderately clear black line in the pectoral clips and as a moderately to very clear black line in the ventral clips (Figure 3).

CONCLUSIONS

Removing the distal half to two-thirds of pectoral fins of 6- to 7-inch bass, and the pectoral or ventral fins of adult (12 inch and larger) walleyes, produced a permanent mark. Although fins frequently regenerated to normal length, thickening and bending of the fin rays along the line of excision was always evident. Partial fin clipping may be used in conjunction with or instead of complete fin removal to substantially increase the number of different groups of fish which can be distinctively marked. Adverse effects of fin mutilation on survival or behavior are probably minimized because initial injury is less severe and partially clipped fins usually regenerate rapidly.

Partial clipping of pectoral, ventral, dorsal and anal fins of rainbow trout averaging 5 inches long failed to produce an easily recognizable

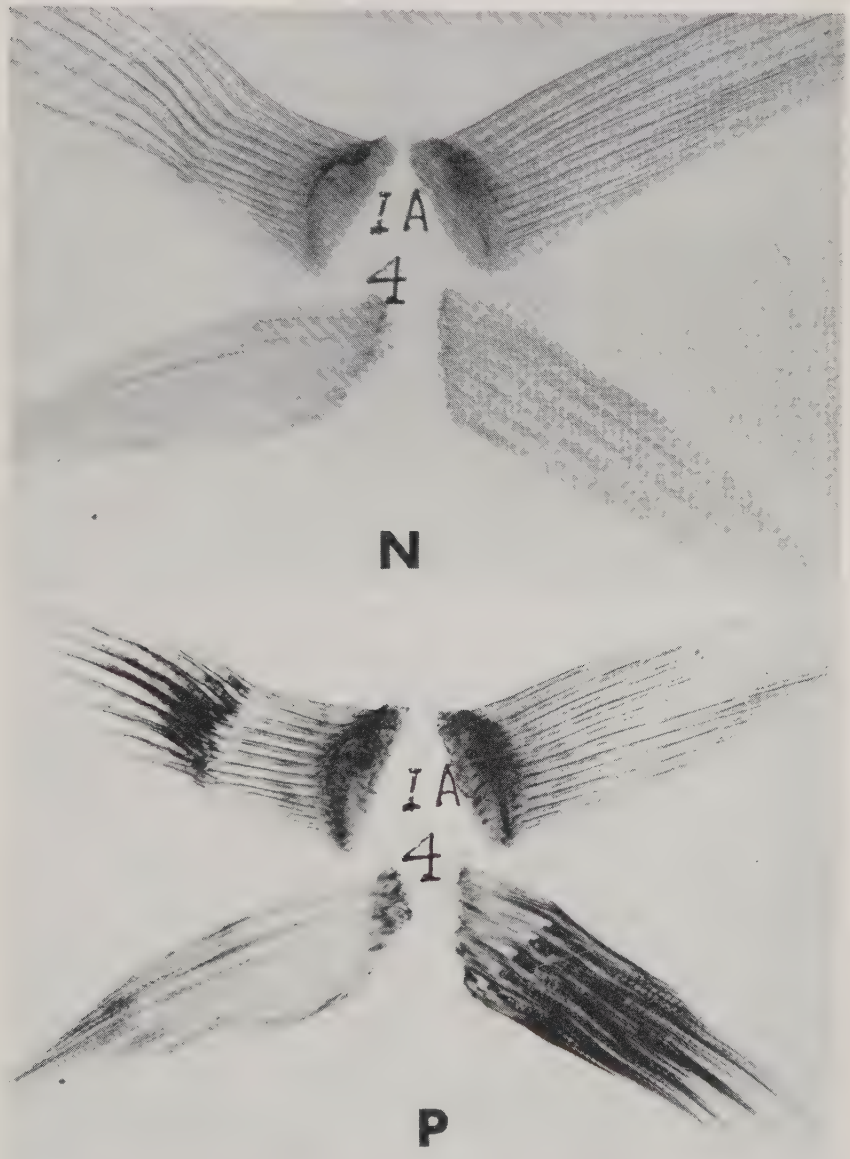

Figure 4. Pectoral and ventral fins of a largemouth bass from same group described under Figure 1, as seen under (N) natural and (P) polarized light.

mark. It is entirely possible that all or some of the partial fin clips used on rainbow trout would have been much more conspicuous had larger fish been used. Treatment of partially clipped fins of rainbow trout with Alizarin Red or Sudan Black produced a coloration at the point of

excision which was evident for 5 months. Partial clipping plus dying holds promise as a means for identifying numerous small lots of fish in laboratory-type experiments where long-term mutilation is undesriable. In most large-scale field operations, the method would be practical only if a tool for simultaneously clipping and dying were developed, and if permanence of the desired dye had been established for the fin clip and species under consideration.

It was found that all partial clips of pectoral and ventral fins encountered in the several experiments, regardless of species or degree of visibility to the naked eye, were clearly revealed when viewed between two polarizers aligned at 90 degrees to each other and with a good light source behind them (Figure 4). This has possible application in some field situations where an investigator, wearing a polarized visor or glasses, could view a questionable fin against a source of polarized light.

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GENERAL NOTES

UNUSUAL CHOICE OF COVER BY WOODCOCK

Daniel Q. Thompson Leader
New York Cooperative Wildlife Research Unit[1]

An unusual choice of cover by woodcock *(Philohela minor)* was observed on Spencer Marsh about 12 miles south of Ithaca (N.Y.). This natural wetland occupies a 100-acre glacial depression and contains several small upland islands. Extending around the major periphery of the marsh, as well as around the islands, is an arborescent shrub border about 10 feet high and 30 feet wide. This border consists of an inner ring of silky dogwood *(Cornus Amomum)* surrounded by gray dogwood *(C. racemosa)* and contains scattered clumps of buttonbush *(Cephalanthus occidentalis)*. Young green ash *(Fraxinus pennsylvanica* var. *lanceolata)*, occasional large swamp white oak *(Quercus bicolor)* and scattered American elm *(Ulmus americana)* also occur around the marsh edge.

Between 2:30 p.m. and 4:00 p.m. on September 27, 1964, while working a dog in a search for sora rails *(Porzana carolina)* in the rush and sedge cover comprising the inner core of emergent vegetation, the author flushed eight woodcock from day roosts in chest-high bulrush *(Scirpus validus)*. Three arose from within a few feet of one another, while the others occurred singly at scattered, isolated roosts. Most of the birds were lying within 30 yards of the arborescent shrub zone which is their normal day-roost cover; however, one was well out in the marsh, about 70 yards from the nearest shrub habitat. All flew directly to the shrub border.

There were borings at the sites where four of the birds were flushed, but the others apparently were not foraging and a small trampled area, with an occasional splashing, indicated that they had been lying quietly in day roosts. Stem densities in these roosting areas were thin enough (10-20 stems per square foot) to allow the birds to move freely. The bulrush stems were still bright green and erect, and the moist, black soil surface was nearly bare with a thin scattering of detritus. A thin understory of sedge *(Carex lasiocarpa)* was present at several of the roost sites.

The same area of bulrush was again covered with the same dog on October 8 between 3:40 p.m. and 5:00 p.m. No fresh sign of woodcock was found in the rushes, and no birds were flushed there. Since ground-water levels were still dropping in the area, it is probable that the rush habitat had become too dry to be attractive. However, two woodcock were flushed together from a stand of green ash saplings with very little understory cover. But there were no signs of boring, and the soil surface under these trees crushed to black organic powder when pinched between the fingers. Apparently these birds were using the site as a day roost.

There seems to be no record in the literature of similar use of bulrush cover by woodcock. However, Pettingill (1936) commented as follows on woodcock activity in dry summers: "The woodcock at such times becomes desperate in its quest for food, boldly appearing on artificially watered lawns and open cultivated fields and gardens during the evenings, even during the daytime." Also, Pearce and Mendall (Mendall and Aldous, 1943) made the following observation on a field trip in late February 1941 ". . . on the White River Refuge near St. Charles, Arkansas, woodcock were frequenting wet sedge fields—cover that appeared much more desirable for Wilson's snipe than for woodcock."

It seems probable that the unusual choice of cover observed at Spencer Marsh was due to the extreme drought brought on by three years of precipitation deficit in the southern Finger Lakes area. According to State Climatologist A. B. Pack (personal communication) the accumulated deficit at Caldwell Field (Ithaca) had at that time amounted to 20 inches—more than half the mean annual preci-

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[1] Contribution of the New York Cooperative Wildlife Research Unit (Ithaca); New York Conservation Department, Cornell University, U.S. Bureau of Sport Fisheries and Wildlife, and Wildlife Management Institute, cooperating.

pitation for this station. George Mouillesseaux, owner of the marsh, stated that this was the first time in his recollection (covering 28 years) that the marsh had gone dry.

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PRESENCE OF SWIMBLADDER IN NORTHERN KINGFISH[1]

Richard *H. Schaefer*
Conservation Biologist
New York State Conservation Department

In his original description of the genus *Menticirrhus*, Gill (1861) used mostly external characteristics and made no mention of a swimbladder. Jordan and Eigenmann (1889), in their review of the Sciaenidae, separated this genus from the genus *Umbrina* primarily on the basis of its having no swimbladder, and this has generally been considered to be the case. Bearden (1963), however, found that juvenile southern kingfish *(M. americanus)* do possess a well developed and probably functional swimbladder which slowly atrophies as the fish grow. Also, Trewavas (1964) reported finding a vestigial swimbladder in two specimens (no size given) of the northern kingfish *(M. saxatilis)*.

In the course of collecting age-length data for the northern kingfish in Long Island waters from 1962 to 1964, it was noted that juveniles possessed a well developed and apparently functional swimbladder. Data, similar to those given by Bearden (1963), were recorded for a series of young-of-the-year and yearling fish collected in 1963 and 1964, respectively, (Table 1). Except for three specimens all the young of the year possessed swimbladders that were, to some degree, inflated, but all the yearlings possessed swimbladders that were totally deflated or atrophied. Apparently, the functional capacity of this organ is lost during the first winter of life. The data suggest that northern kingfish attain a larger size (210 millimeters in total length) than southern kingfish (125 millimeters in standard length as given by Bearden) at the time of complete deflation and that the change is more abrupt.

[1] A contribution of Federal Aid in Fish and Wildlife Restoration Project F-15-R. Whether or not this phenomenon is related to the different environments inhabited by juveniles and adults is unknown, although adaption to environmental change is a possibility. Juvenile northern kingfish are usually found in the relatively quiet waters of estuaries where a swimbladder might be an asset in feeding and in escaping from predators. The adults, however, primarily inhabit the turbulent ocean surf where the absence of a swimbladder might be more advantageous to survival.

TABLE 1. CONDITION OF SWIMBLADDER IN RELATION TO AGE AND LENGTH OF 585 YOUNG-OF-THE-YEAR AND YEARLING NORTHERN KINGFISH FROM LONG ISLAND WATERS

Total length of fish (millimeters)	Number of specimens	Condition of swimbladder			
		Average length (millimeters)	Degree of inflation (per cent)		
			Fully inflated	Partially inflated	Deflated or atrophied
Young of the year (collected in 1963)					
20– 29	19	5.6	94.4	5.6	..
30– 39	57	7.5	91.2	8.8	..
40– 49	32	9.6	84.4	15.6	..
50– 59	42	11.3	78.6	21.4	..
60– 69	23	13.1	78.3	21.7	..
70– 79	42	13.5	76.2	23.8	..
80– 89	50	14.0	75.0	25.0	..
90– 99	31	15.7	87.1	12.9	..
100–109	20	16.9	85.0	10.0	5.0
110–119	19	17.9	73.7	26.3	..
120–129	11	20.3	81.8	18.2	..
130–139	22	20.5	91.0	4.5	4.5
140–149	26	23.3	96.2	3.8	..
150–159	26	25.7	100.0	..	..
160–169	31	26.1	90.3	9.7	..
170–179	16	27.0	87.5	12.5	..
180–189	5	25.8	80.0	..	20.0
190–199	2	25.5	100.0	..	..
200–209	1	32.0	100.0	..	..
Yearling (collected in 1964)					
210–219	1	32.0	..	..	100.0
220–229	6	35.8	..	..	100.0
230–239	17	35.7	..	..	100.0
240–249	34	36.2	..	..	100.0
250–259	23	39.2	..	..	100.0
260–269	14	34.4	..	..	100.0
270–279	10	39.5	..	..	100.0
280–289	3	38.0	..	..	100.0
290–299	2	39.5	..	..	100.0

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INDEX FOR VOLUME 12

Abramson, Harold A., see Loeb, Howard A., 79
Age and growth, kingfish, 191
Alkon, Philip U. Some effects of weather and other influences on summer roadside counts of cottontails, 180
Alkon, Philip U., and George H. Teidman. Summer roadside observations of marked cottontail rabbits, 71
Alperin, Irwin M. Recent records of pugheaded striped bass from New York, 114
Algal epibiosis and parasitism in blueback herring, 116
Alperin, Irwin M., and Richard H. Schaefer. Marine fishes new or uncommon to Long Island, New York, 1
Angler success
sport fishery in surf on Long Island, 40
stocked trout in streams, 172
winter flounder, 62
Apmann, Robert P., and Maurice B. Otis. Sedimentation and stream improvement, 117

Bass, striped, recent records of pugheaded individuals, 114
Bluegill, conversion of 4-(2,4-DB) to 2,4-D by, 108
Briggs, Philip T. The sport fishery in the surf on the south shore of Long Island from Jones Inlet to Shinnecock Inlet, 31
The sport fisheries for winter flounder in several bays of Long Island, 48
Burdick, George B., *et al.* Toxicity of Sevin (carbaryl) to fingerling brown trout, 127

Carbaryl (see Sevin)
Colby, David, see Burdick, George B., 127
Composition of catch
kingfish taken by seining, 205
sport fishery in surf on Long Island, 37
winter flounder according to facility, 59
Cottontail
roadside observations of marked animals, 71
summer roadside counts in relation to weather, 180

Dean, H. J., see Burdick, George B., 127
Deer
population composition, 24
population dynamics, 17
productivity, 27
reproduction rate, 21
Dibrom-malathion, as a selective piscicide, 99
D-lysergic acid derivatives
effect on surfacing behavior of fish, 79
effect of ultraviolet light on, 95
Dove, mourning
as a game bird, 165
breeding, 161
crop gland development, 162
distribution and abundance, 149
ecology, 147
food habits, 153
movement of juveniles, 165
sex ratio, 151
weight, 152

Eipper, Alfred W., and John L. Forney. Evaluation of partial fin clips for marking largemouth bass, walleyes and rainbow trout, 233

Fin clips, for marking fish, 233
Fish, occurrence of uncommon species in Long Island waters, 1
Fish, behavior, effect of d-lysergic acid, 82
Fishery, sport
for winter flounder, 48
in surf on south shore of Long Island, 31
Fishing facilities, on Long Island, 50

Fishing pressure
for winter flounder, 51
relation to trout stocking, 170
surf fishery on Long Island, 33

Flounder, winter
catch statistics, 59
characteristics of fish taken, 64
sex ratio, 69
sport fishery on Long Island, 48

Food habits, mourning dove, 153

Forney, John L. Factors affecting growth and maturity in a walleye population, 217
also, see Eipper, Alfred W., 233

Gettner, Henriette H., see Loeb, Howard A., 79

Growth and maturity
kingfish, 211
walleye, 217

Gutenmann, Walter H., and Donald J. Lisk. Conversion of 4-(2,4-DB) herbicide to 2,4-D by bluegills, 108

Harris, E. J., see Burdick, George B., 127

Herbicide—4-(2,4-DB), conversion to 2,4-D by bluegills, 108

Herring, blueback, parasitism, 116

Hesselton, William T., *et al.* Population dynamics of deer at the Seneca Army Depot, 17

Hoff, James G., and James R. Westman. Experiments with a dibrommalathion formulation as a selective piscicide, 99

Huver, Charles W. Occurrence of a northern pike in Fisher's Island Sound, 113

Kelly, William H. A stocking formula for heavily fished trout streams, 170

Kingfish, northern
age and growth, 191
age and maturity, 211
age-length relationship, 201
commercial catch, 192
length-weight relationship, 204
mortality, 210
population composition, 205
scale growth and annulus formation, 194
spawning period, 213
swimbladder, 242

Kingfish, southern, first record for Long Island, 112

Lehner, Philip N. Some observations on the ecology of the mourning dove in New York, 147

Loeb, Howard A., *et al.* Effect of 48 derivatives of d-lysergic acid on the surfacing behavior of laboratory fish, 79

Long Island
occurrence of uncommon fishes, 1
sport fishery for winter flounder, 48
sport fishery in surf, 31

Management
deer, 18
mourning dove, 165
trout, 170

Methods and techniques
marking rabbits, 71
partial fin clips for marking fish, 233
roadside census of rabbits, 71
scale characteristics as criteria of age and growth of fish, 194, 218
stocking formula for trout, 170

Mortality, kingfish, 210

Otis, Maurice B., see Apmann, Robert P., 117

Pike, northern, in Fisher's Island Sound, 113

Population composition
deer, 24
kingfish, 205
walleye, 219

Productivity, deer, 27

Rabbit, see cottontail

Reproduction
deer, 21
kingfish, 213
mourning dove, 161
walleye, 220

Schaefer, Richard H. First record of the southern kingfish from Long Island, New York, 112
Age and growth of the northern kingfish in New York waters, 191
Presence of swimbladder in northern kingfish, 242
also, see Alperin, Irwin M., 1

Sedimentation, relation to stream improvement, 117

Seneca Army Depot
history of deer population, 18
nature of deer range, 17

Severinghaus, C. W., see Hesselton, William T., 17

Sevin
effect of temperature on toxicity, 138
toxicity to brown trout, 127
toxicity in hard and soft water, 136
Sex ratio
mourning dove, 151
winter flounder, 69
Skea, Jack, see Burdick, George B., 127
Stream improvement, 117
Streams, behavior, 118
Tanck, John E., see Hesselton, William T., 17
Thompson, Daniel Q. Unusual choice of cover by woodcock, 241
Trout, stocking formula, 170
Trout, brown, toxicity of Sevin to, 127
Turtle, red ear, effect of d-lysergic acid, 94
Walleye
angling mortality, 230
annulus formation, 218
body-scale relationship, 223
growth and maturity, 217
growth of year classes and age groups, 223
population composition, 219
population density, 228
Weather, effect on roadside counts of cottontails, 180
Westman, James R., see Hoff, James G., 99
Woodcock, choice of cover, 241